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GEOLOGY,

INTRODUCTORY, DESCRIPTIVE, AND PRACTICAL.

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GEOLOGY,

INTRODUCTORY, DESCRIPTIVE, & PRACTICAL.

BY

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TO

THE REV. ADAM SEDGWICK, M.A. F.R.S., &c.,

FELLOW OF TRINITY COLLEGE, AND WOODWARDIAN PROFESSOR

OF GEOLOGY IN THE UNIVERSITY OF CAMBRIDGE,

THIS WORK,

EMBODYING THE PRINCIPLES WHICH HE HAS TAUGHT,

AND ILLUSTRATING THE SCIENCE WHICH HIS LABOURS HAVE

GREATLY CONTRIBUTED TO ADVANCE,

IS DEDICATED,

BY HIS AFFECTIONATE PUPIL

AND SINCERE FRIEND,

THE AUTHOR.

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The diagrams not marked are either original, or have been copied without reference. The vignettes, &c., not marked, are chiefly from original sketches, for which I am indebted to the kindness of friends.

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a The Transactions of the Geological Society of London.
b Fossiles des Terrains de Transition de la Belgique, par L. de Koninck.
c Recherches sur les Poissons Fossiles, par L. Agassiz.
d Dr. Buckland's Bridgwater Treatise on Geology and Mineralogy.
e Owen's Lectures on the Invertebrata.
f Mantell's Geology of the South-east of England.
g Bronn's Lethæa Geognostica.
h Faujas de St. Fond, Recherches sur la Montagne de St. Pierre à Maestricht.
i The Silurian System, by Roderick Impey Murchison, Esq.
k Hugh Miller, on the Old Red Sandstone of Scotland.
l Traité de Geognosie, par M. d'Aubuisson.
m Mémoires de la Société Linnéenne de Normandie.
n Phillips' Geology of Yorkshire.
o Report on the Geology of Cornwall, Devon, and west Somerset, by Sir H. T. De la Beche.
p Humboldt's Vues des Cordilleras.
q Backhouse's Narrative of a Visit to the Australian Colonies.
r Voyage de l' Astrolabe, par M. d' Urville.

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OF THE

ORDER OF SUPERPOSITION OF THE DIFFERENT FOSSILIFEROUS STRATA AND GROUPS OF STRATA.

TERTIARY PERIOD.

	BRITISH ROCKS.	CHARACTERISTIC FOREIGN EQUIVALENTS.
SUPERFICIAL DEPOSITS, or *PLEISTOCENE.*	*Diluvium* and *Alluvium.* Superficial deposits of gravel and other transported materials covering the regularly stratified rocks in all countries, and sometimes stratified.	
NEWER TERTIARY, or *PLIOCENE.*	*Till* of the Clyde Valley. Norwich or Mammaliferous crag.	Newest Sicilian beds. Loess of the Rhine. Brown coal of Germany. Subapennine beds.
MIDDLE TERTIARY, or *MIOCENE.*	Red Crag. Coralline Crag.	Basins of the Loire and Garonne. Basin of the Rhine. Molasse of Switzerland. Basin of Vienna.
OLDER TERTIARY, or *EOCENE.*	Bagshot sand. London clay.	Paris basin. Basin of Brussels. Freshwater beds of Auvergne in central France, and of the south of France.

NEWER SECONDARY PERIOD.

CRETACEOUS SYSTEM.		Maestricht beds.
	Upper chalk (with flints).	
	Lower chalk (without flints).	
	Chalk marl.	Craie tufau.
	Upper greensand.	Plänerkalk.
	Gault.	
	Lower greensand.	Quadersandstein. Neocomien.

MIDDLE SECONDARY PERIOD.

	BRITISH ROCKS.	CHARACTERISTIC FOREIGN EQUIVALENTS.
WEALDEN FORMATION.	Weald clay. Hastings sand. Purbeck beds.	
OOLITIC SYSTEM. (*Upper*)	Portland stone. Portland sand. Kimmeridge clay.	Lithographic limestone. Argile de Honfleur.
(*Middle*).	Upper calc grit. Coral rag. Lower calc grit. Oxford clay. Kelloway rock.	Nerinæan limestone. Argile de Dives.
(*Lower*.)	Cornbrash. Forest marble. Great Oolite and Bradford clay. Stonesfield slate and Fuller's earth. Inferior Oolite. Calcareous sand.	Calcaire á polypiers. Calcaire de Caen.
LIASSIC GROUP.	Upper Lias shale and marlstone. Lower Lias shale. Lower Lias limestone.	

OLDER SECONDARY PERIOD.

UPPER NEW RED SANDSTONE, or *TRIASSIC SYSTEM.*	Saliferous red and variegated marls. Red Sandstones and conglomerates.	Keuper (*Marnes irrisées*). Muschelkalk. Bunter sandstein (*Gres bigarré*).

NEWER PALÆOZOIC PERIOD.

MAGNESIAN LIMESTONE, or *PERMIAN SYSTEM.*	Magnesian limestone. Lower new red sandstone .	Zechstein. Shaly beds with Kupferschiefer. Rothe-todte-liegende. N.B. The Russian equivalents of this system form a beautiful and perfect series of fossiliferous rocks in the ancient kingdom of Permia, whence the name Permian system.

NEWER PALÆOZOIC PERIOD *continued.*

	BRITISH ROCKS.	CHARACTERISTIC FOREIGN EQUIVALENTS.
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MIDDLE PALÆOZOIC PERIOD.

DEVONIAN SYSTEM, or *OLD RED SANDSTONE.*	Slates and limestone of Devonshire. Conglomerate, cornstone, and tilestone, of Herefordshire and Scotland.	Calcareous shales, limestones and conglomerates of Belgium, Westphalia, &c. Marlstones, limestones of a yellow and white colour, and conglomerates of Russia.

OLDER PALÆOZOIC PERIOD.

UPPER SILURIAN ROCKS.	Ludlow and Wenlock series, and Upper Cumbrian and Cambrian rocks.	Grauwacké and slaty flagstones and slates of Germany, Belgium, Brittany, &c. Clays, sandstones, &c., of Russia, both European and Asiatic.
LOWER SILURIAN ROCKS, or *PROTOZOIC SERIES.*	Caradoc sandstone and Llandeilo flags, and older Cumbrian and Cambrian fossiliferous slates.	Shales, grauwacké sandstones and slates, &c., of Scandinavia, and of many parts of North and South America, Africa, Australasia, &c.

N. B.—Where the name of no foreign equivalent appears, the English designation of the rocks has been adopted on the Continent or simply translated.

GEOLOGY:

INTRODUCTORY, DESCRIPTIVE, AND PRACTICAL.

PART THE FIRST.

INTRODUCTORY.

CHAPTER I.

DEFINITION.—OBJECT OF THE WORK.—EFFECTS PRODUCED ON THE PHYSICAL FEATURES OF THE GLOBE BY CAUSES NOW IN ACTION.

Geology is both an important branch of Natural History, and also a link by which all the other departments of Natural History are brought into relation with the exact Sciences. Its object is to observe and describe the structure of the external crust of the globe; and, from the consideration of phenomena there presented to view, to trace the successive changes that have taken place upon the earth, and the various laws, or modes of action, which the Author of Nature has seen fit to employ in effecting these changes.

Immediately subservient to Geology, and necessary to be in some measure understood, in order that the student may recognize and class the various materials of the earth's crust, are the sciences of Mineralogy and Chemistry; and, since the remains of organized bodies, both animal and vegetable, are frequently met with among the mineral substances of which rock formations are composed, our Science is also intimately connected both with Zoology

and BOTANY. These relations, and the nature and extent of Geological phenomena, being once recognised and understood, the establishment of theoretical views follows as a matter of course; and the Geologist is in a condition to prepare for the Mathematician and the Astronomer, a series of problems second to none in the interest which attaches to them, or the importance and generality of the laws deduced from their solution.

Geology is thus, in its highest and most perfect state, the enunciation of laws, which, acting through successive ages, have at first produced, and since continually modified, the external surface of the globe; and viewed in this light it is only less general and extensive than Astronomy, because the researches of this latter Science have reference to other planets, and to the whole material universe. While, however, the ultimate object of Geology is so comprehensive, and it is thus a real history of nature, the numerous facts upon which its conclusions rest are dependant on some one or other of the different branches of Natural History, commonly so called; and a knowledge of these facts, as connected with the structure of the earth, and its former as well as present inhabitants, is essentially necessary to the student before theoretical views are introduced to his notice. In the work I am now undertaking, it is my object to acquaint the reader with the nature of the *foundations* of the science of Geology; and the superstructure—by which I understand the theories, and the laws deduced—will not be allowed to detain us long, because, however interesting they may be, they can only be instructive to the advanced and perfect Geologist. I trust, however, I shall be able to show that the facts themselves upon which the theories are founded, are sufficiently numerous and important to deserve the most careful consideration; that the acquirement of a general

knowledge of these facts is, therefore, an object not unworthy the serious attention of all those who are interested in the works of Nature; that it is an object not only deeply interesting, but permanently and immediately useful, and eminently practical; and, lastly, that such knowledge is to be acquired,—as, indeed, useful knowledge of all kinds must be acquired,—not by wildly and weakly systematising, and making gratuitous suppositions to strengthen groundless hypotheses, but by calm, sober observation, founded upon, and directed by, an acquaintance with what has been already effected, and having constantly in view the elucidation of truth, not the establishment of a theory.

My object in this work is twofold:—In the first place, I shall endeavour to give such an account of what is certainly known in Geology, as may put the reader in a condition to examine and investigate for himself, and make use of those numerous and valuable stores of knowledge contained in museums, and described in detail by many admirable naturalists. In the second place, I shall lay before him a sketch of the applications of Geology to the Arts; in order that, if possible, I may be the means of attracting more attention to this important branch of the subject than has hitherto been given by those whose profession requires, or whose inclination leads them to the pursuits of Mining or of Engineering, of Architecture or of Agriculture.

In proceeding with my account of the subject, under the heads of Descriptive and Practical Geology, I shall, indeed, from time to time, introduce such generalisations as seem compatible with the object of a work professedly elementary; and without at all dwelling upon theory, I shall endeavour to communicate distinct notions and general views of the various phenomena that will come under our notice,

by grouping together classes of facts of the same kind, belonging to the same period, or occupying the same relative position among stratified rocks.

Such being the plan I mean to adopt, I shall not dwell upon the early history of Geology, or pretend to give any minute account of the causes which now tend to modify the physical features of the earth; although, with regard to the latter, I cannot pass, without some allusion, a part of the subject so important and instructive, and which is of so much use in explaining the real nature of many remarkable phenomena purely Geological. Both of these matters have, however, been so admirably treated in Mr. Lyell's "Principles of Geology," that I have only to refer to that work for more complete and satisfactory detail. I desire simply to inculcate and enforce a knowledge of the elements of Geology; understanding by that expression an account of observations which have reference to the arrangement of the materials of which the superficial crust of the earth is formed, the nature of those materials, and the strange and interesting remains of organic life so abundantly spread through them, and indicating so remarkably the ancient condition of the earth's surface.

It is from these facts, or facts such as these, that conclusions and theories really valuable must be elaborated; without a familiar acquaintance with them no generalization should be hazarded, no objections should be raised or answered, and no value attached to any view or supposition, however plausible. They are as stones fitted to construct the foundations of the science; they are solid, massive, and permanent; no prejudice, no expression of opinion or authority, can disturb them, but they remain ready to be employed for the benefit of those who are really desirous of acquiring true and useful knowledge.

Having offered these prefatory remarks, I proceed now to explain certain preliminary matters necessary to be understood before considering in detail the wide field of descriptive geology; and I shall endeavour to render my explanations as clear as possible, and as brief as is consistent with the importance of the subject.

The first examination of *structure*, when a young geologist seeks to familiarise himself with the rocks of which the earth's surface is made up, brings to light a peculiarity which cannot fail to attract notice. It is the appearance of bedding, or stratification, presented in the great majority of cases, when the superficial coating of vegetable soil is removed, or a vertical section seen—an appearance indicating clearly the mechanical origin of the formation; or, on the other hand, when this is not the case, a peculiar crystalline structure is observable, unaccompanied by any regular stratification, and apparently caused by the gradual cooling of a rock from a state of igneous fusion. Now it is one great object of a geologist, in making himself acquainted with the structure of a district not yet familiar to him, to determine the fact, as to whether the rocks are stratified or unstratified, for upon this depends in a great measure their aqueous or igneous origin; and thus the result of a mere cursory and superficial observation becomes a step in the general classification of rocks. Let us proceed to consider, in the first place, the nature of those rocks which exhibit an appearance of stratification.

It requires but little study to discover that every one of the most common and daily operations of nature is concerned more or less in the formation of stratified rocks. Every shower of rain that falls in a hilly or mountainous district, every brook or river that pursues its course through a greater or less extent of country to the sea, or is swallowed

up before reaching the sea in some mightier stream than its own, every lake or pool that receives the waters of a river loaded with the particles of muddy soil over which it has passed, and pours forth at its opposite extremity a transparent stream cleared of impurities, every wave that dashes against a projecting rock on the sea coast, or washes into a hollow bay, tearing and grinding away the solid cliff: —each one of these, together with other not less powerful though less frequently recurring agents, is concerned in the formation of new strata, and in effecting changes in the physical conformation of the globe scarcely less remarkable than those with which the geologist has to deal, and which will hereafter be described. A few instances of the actual extent of the effect thus produced will form a useful and interesting introduction to a description of geological facts analogous to them.

Of the many constantly recurring phenomena, which, owing to their perfect and undeviating regularity attract but little notice from the casual observer, there is none perhaps more remarkable than the quantity of solid matter held for a time in mechanical suspension in the water of rivers, and brought down to be deposited at the mouth of the stream, or spread over the bed of the ocean. The vast amount of mud thus conveyed by running water is occasionally seen in the extensive deltas, or tracts of swampy land, at the mouths of great rivers, such as the Rhine, the Po, the Nile, the Ganges, &c.; in each of which cases the river divides into so many channels before reaching the sea, that its actual character and apparent magnitude is completely lost.

The origin of these vast deposits of rich alluvial soil must be sought for entirely in mud brought from the high lands or the plains through which the river passes, and held in suspension so long as the water is in rapid motion, but which sinks

to the bottom when the current is checked. To obtain some notion of the actual quantity of solid matter thus continually brought down from the high land to the sea, an experiment was made some years ago by Mr. Leonard Horner,* on the water of the Rhine, the calculations founded on which possess considerable interest. Mr. Horner found that in the month of August, when the river was unusually low, one cubic foot of water taken fairly from near the middle of the river, near Bonn, supplied rather more than 21 grains of solid matter, and that in the month of November, when the water was turbid, about 35 grains of residuum were obtained. Now, taking the average of these two observations, and considering the Rhine at Bonn to be 1200 feet wide, to have a mean depth of 15 feet, and to run with a mean velocity of $2\frac{1}{2}$ miles per hour, it appears that nearly 400 tons of solid matter would pass down the stream per hour; and that in the course of one year, between seven and eight thousand millions of tons would be carried along, the greater part of which must be deposited in Holland before reaching the sea, in consequence of the slow and meandering course of the river through that flat alluvial country. In the course of 2,000 years, the Rhine may thus have brought down enough material to form a stratum one yard thick, extending over an area more than 36 miles square.

But the delta of the Ganges far surpasses in magnitude that of any European river; and is on the whole, perhaps, the most extensive and remarkable of all those at present forming of which we have any accurate data. The head of this gigantic delta commences at a distance of 220 miles in a direct line from the sea, and the base of it is 200 miles in length; the whole triangular space occupied comprising

* Edinb. Phil. Journ. for 1834—5, p. 105.

upwards of 20,000 square miles, every part of which has been formed by deposition from the river and its tributaries.

The quantity of mud and sand carried by the Ganges into the Bay of Bengal is however, notwithstanding the vast deposit which previously takes place, still so great, that during the rainy season when the stream is turbid, the sea does not recover its transparency even at a distance of 60 miles from the coast; and the quantity of mud held in mechanical suspension is so great, that a glass of water taken out of the river when at its height, is said to yield one part in four of mud. Calculating from the dimensions of the river and the rate of the current, Major Rennel has shown that during the flood season the weight of the mud thus brought down daily, and deposited either within the limits of the present delta, or at the mouths of the different branches, must be as much as 450 millions of tons, a quantity which is perhaps more readily understood by expressing it as equal to about 74 times the weight of the Great Pyramid of Egypt, supposing that to be a solid mass of granite.

Another instance of a vast amount of solid matter conveyed by a river, and spread out upon the bottom of the ocean, is seen in the distribution of the sediment of the great river of the Amazons. At the point where the current formed along the coast of Africa, (a current which crosses the Atlantic to the continent of South America,) meets the stream of the Amazons, it runs at the rate of about four miles per hour. The stream of the river, however, preserves part of its original impulse, and its waters may be recognised by their muddy colour, and are not wholly mingled with those of the ocean at a distance of 300 miles from its mouth. An immense tract of swamp is being formed along the coast of Guiana by the deposit of the mud

thus brought down by the Amazons, and the shallow sea along that coast is rapidly being converted into land.

The power of water when in motion of transporting not only mud, but heavy bodies of considerable magnitude, is another point of considerable interest in Geology, and one that requires to be stated in some little detail, because there are certain popular fallacies concerning the motion of heavy bodies, which tend much to confuse and mislead the judgment on this subject.

We are accustomed to consider weight as an absolute quality of certain bodies, which we therefore call heavy. Now this quality of weight, as the word is commonly applied, is in fact only relative; and in this relative sense, a piece of wood is no more heavy when immersed in water than a balloon filled with hydrogen gas is in the air, each being lighter or of less weight than an equal quantity of the element in which it is placed, and which it displaces. In all cases, the actual weight of that quantity of the fluid which would have occupied the space filled by a solid body, must be deducted from the actual weight of the body before the relative weight,—the only part which resists motion,—can be calculated.

Speaking accurately, therefore, bodies of all kinds are heavier in air than they are in water, and are consequently moved with greater facility in the latter, than in the former fluid. It should also be borne in mind that the power which water possesses, of transporting heavy bodies, increases in an enormous ratio with the increase of rapidity of the current; and with these considerations, we shall be able to account for, and understand statements on record, otherwise almost incredible, of the effects produced by water in rapid motion.

As a recent instance of effects of this kind, and one

occurring in our own island, I quote an account of an extensive flood, which spread simultaneously over a large tract of country, in Aberdeenshire, in the early part of August 1829. The total length of river flooded on this occasion could not be less than between five and six hundred miles, and the whole of the river courses were marked by the destruction of bridges, roads, crops, and buildings.

Speaking of the river Nairn, Sir T. D. Lauder relates, in a detailed account of this flood, that a fragment of sandstone rock, fourteen feet long, three feet wide, and one foot thick, and which could not have weighed less than three tons, was carried down the river a distance of two hundred yards.

A bridge over the Dee having five arches, and a water-way of two hundred and sixty feet, which was built of granite, and had stood uninjured for twenty years, was carried away by the flood, and the whole mass disappeared from the bed of the river.

"The river Don," says Mr. Farquharson, describing the effects of the same flood; "has, upon my premises, forced a mass of four or five hundred tons of stones, many of them weighing as much as 2 or 3 cwt., up an inclined plane, rising six feet in eight or ten yards, and left them in a rectangular heap, about three feet deep on flat ground."

When we remember how inconsiderable are the rivers and streams of our own island compared with those of the Alps and other mountain chains, where such floods also are much more frequent, we may easily imagine that the quantity of superficial matter moved and deposited in this way, as well as by rivers in all parts of the world, must be very great, and that strata must now be forming which, in the course of ages, may effect important modifications of the surface of the globe; and, at some future time,

when that which is now the bottom of the sea shall be elevated into islands and continents, the effects of all these causes, now in action, will be seen upon the dry land.

But these effects of running water, important as they may seem, are trifling when brought into comparison with the quantity and magnitude of the blocks removed in the northern seas, and in Alpine districts, by the agency of ice, and by those masses of frozen snow called Glaciers. The surface of glaciers is usually loaded with broken fragments of rock, arranged in long ridges or *moraines*, sometimes thirty or forty feet high, and many miles in length; and in the North seas masses of frozen gravel, of a similar kind, are constantly being pushed forwards into the sea and are there broken off, forming floating islands of ice which drift downwards into lower latitudes and warmer seas, gradually depositing, in their course, the rocks and fragments with which they are charged. To give an idea of the extent to which deposits of gravel are now going on by these means in northern latitudes, it may be sufficient to state that Mr. Scoresby counted, in view at one time, as many as five hundred icebergs drifting along in latitude 69° and 70° N; these bergs rising above the surface to a height varying from one to two hundred feet, and measuring from a few yards to a mile in circumference at the water line; and, as the mass of ice below the water, is known to be always seven or eight times greater than that which appears above it, and the whole is loaded with fragments of rock, the effect of the gradual melting of such masses must inevitably be, to strew the bed of the sea with a vast quantity of gravel and erratic blocks.

The weight of the solid material of earth and stones in one of the larger of these icebergs, cannot be less than from fifty to a hundred thousand tons; and they have been known

to drift from Baffin's Bay to the Azores, and from the South Pole to the immediate neighbourhood of the Cape of Good Hope.

The gradual wearing away of solid rocks, by the action of water passing over them, is another cause constantly tending to destroy existing inequalities of the surface, and deposit the materials in beds at the bottom of the sea. In one instance on record, a torrent of hard blue lava, ejected from one of the craters near the summit of Mount Etna, had crossed the channel of the Simeto, the largest of the Sicilian rivers, and had not only occupied the channel, but crossing to the opposite side of the valley, had accumulated there in a rocky mass. The date of this eruption is supposed to be 1603; and, at any rate, it is one of the most modern of those of Mount Etna; but now, after the lapse of little more than two centuries, the river has cut a passage for itself through the lava from fifty to one hundred feet wide, and in some parts from forty to fifty feet deep.*

But the power of marine currents, and the ceaseless dash of the waves of the ocean, are much more striking in their effects than the quiet action of a river. As instances of this the condition of the various promontories of chalk, on the South coast of England, and the opposite coast of Normandy, is too well known to require more than a passing allusion; but on the Northern and more exposed shores, both of the main land and the western Islands of Scotland, this power is exhibited on an extremely grand scale. In what is called the Grind of the Navir, in the Shetland Isles, the sea is constantly widening a passage it has cut for itself, through cliffs of the hardest porphyry, tearing down huge fragments of rock, and depositing them

* Lyell's Elements of Geol. vol. i. p. 259.

at a considerable distance. In this way, from time to time, islands have been separated from the main land, and the islands themselves split, as it were, into shreds; until at last even these bare bones, the skeleton of what was once land, have also been swept away, the last victims to the restless violence of moving water.

The ordinary force of marine currents is also, under some circumstances, very remarkably shown. During the erection of the well known Bell Rock lighthouse, at the mouth of the Tay, six large blocks of granite, which had been landed on the reef of the Bell Rock at low water, were, on one occasion, removed by the force of the sea as the tide rose, and thrown over a ledge to the distance of twelve or fifteen paces; an anchor weighing about twenty-two hundred weight being, on the same occasion, thrown upon the rock.

Along the whole of the eastern coast of England the waves are ceaselessly occupied in washing away the different projecting headlands that stretch into the sea. In various places in Yorkshire, Norfolk, and Suffolk, houses, churches, and even whole villages, are, from time to time, swallowed up, and the advance of the sea is sometimes extremely rapid. At Sherringham, in Norfolk, a house was built in 1805 at the distance of fifty yards from the cliff, which, however, has receded so rapidly, that in the year 1829, after the lapse of less than a quarter of a century, there remained only a very small garden between the house and the sea, as much as seventeen yards of cliff having been swept away in the course of the five last years only. In the harbour of the same port (Sherringham) there is now at one point a depth of twenty feet of water, where, less than fifty years ago, there stood a cliff fifty feet high; and a little further to the south, where the cliffs are composed

of alternating strata of clay, gravel, loam, and sand, large tracts of land are not unfrequently swallowed up by the sea, being undermined by the waves, or by springs of water rising and penetrating between the beds. Many other extensive landslips have occurred, from time to time, on the south coast of England, and also on the western coast, where the county of Cheshire has suffered a loss of many acres of land between the Mersey and the Dee, by the gradual advance of the sea upon the abrupt low cliffs of red clay and sand.

It cannot be necessary to dwell longer on the fact, which must by this time be evident, that there is, in all the forces we have been considering, a tendency to destroy the inequalities with which the earth's surface is covered, and to deposit the material thus separated in horizontal layers at mouths of rivers, and at the bottom of lakes and seas. Without some other force acting in opposition to this, there must have been, from the commencement of the present condition of things, a constant approach to a period when the water should have done its work, and left no land to wash into mud, and no cliff to grind to powder. But this is not at all the actual state of the case; and, on examining and observing a little more minutely, it is not difficult to discover that an antagonist force is acting; and that, in different parts of the world, the effect of subterraneous fire is doing as much to restore and produce inequalities of the surface, as the waters of the ocean do to destroy them; and we shall find earthquakes and volcanic eruptions producing at intervals certain effects which may well compare even with the most extensive of those we have just recorded.

In order to understand the real nature and extent of volcanic action, we must not merely direct our attention to

one or two of the more remarkable active volcanoes, but, taking into account all that is known of the extent and direction of those disturbances of which we have any satisfactory history, bring into one view, so far as we can, the facts presented to our notice. Nor is this difficult, for by reference to the map, it will be found easy to connect together the different points at which volcanic eruptions have taken place, into a limited and even a small number of groups, and we may consider each group as having a distinct centre of action. In Europe, for instance, there are five such groups, three of which are not far removed from each other, namely, Vesuvius including Ischia, Etna and the Lipari Islands, and the Greek Archipelago; while the two others, namely Iceland and the Azores, are apparently totally unconnected and isolated.

In Asia Minor, along the borders of the Mediterranean and on the shores of the Black Sea, the Caspian and the Persian Gulf, there is also abundant evidence of the existence of volcanic fires; but these are as nothing compared with the band of intense volcanic activity extending along the eastern borders of Asia, and constituting, beyond all doubt, one of the most remarkable physical features of the globe. This band, including in an extensive curve the islands of Sumatra and Java, the Eastern Moluccas, and the Philippine Islands, is not less than 5,000 miles in length, and has an average breadth of about 250 miles. But the same line may also be traced northwards and eastwards, at least 4,000 miles further towards the extreme north-eastern part of the continent of Asia; and it there appears to connect itself by means of several volcanic cones in the Aleutian Islands with other volcanic districts in North-western America.

The whole length of the two Americas again, from the Rocky mountains through Mexico to the Andes, and thence

to Patagonia, exhibits distinct traces of recent volcanic activity extending to Tierra del Fuego and throughout the whole distance extremely narrow, and closely approaching the boundary of the Pacific Ocean. The Pacific itself seems also to be a vast theatre of similar action, occasionally made manifest by a line of volcanic islands, and still more frequently indicated by coral reefs and lagoon islands, the occurrence of which can only be satisfactorily accounted for by some cause connected with volcanic phenomena.

Most of the islands round the continent of Africa exhibit more or less clearly marks of recent volcanoes; and as much as is at present known of Australia proves it to be no exception to the older continents in this matter.

Notwithstanding that the appearance of the action of subterraneous fire is so universal throughout the world, it is in most cases confined to a very narrow band, almost always adjoining a sea-coast, or forming, as in the great Asiatic Archipelago, a string of islands in an extensive ocean. The actual points of eruption also are generally few; but there is usually quite sufficient proof of these different points being connected underground, as well from the direction of the earthquakes which usually precede an eruption, as from the fact, that when one volcano is active the rest, belonging to the same group, are commonly in a state of repose.

Of the active volcanoes of recent times those of America and Asia are the most remarkable; and a group of five, traversing Mexico from west to east, was, in the course of the last century, the seat of one of the grandest and most effective eruptions on record.

These volcanoes rise from an extensive platform, distant about 36 leagues from the sea, and elevated between 2,000 and 3,000 feet above the sea level; and, in the year 1759,

the plain of Malpais, which forms part of the platform, was disturbed from the month of June till August by hollow sounds and a succession of earthquakes; and, in September, flames burst from the ground, and fragments of burning rocks were thrown to a prodigious height. Six volcanic cones were then formed; of which Jorullo, the central one, was elevated 1600 feet above the plain, and continued burning, sending forth streams of basaltic lava till the month of February in the succeeding year. None of the other cones were less than 300 feet in height. Twenty years after the eruption this spot was visited by Humboldt, who found around the base of the cones, and spreading from them as from a centre, a mass of matter 550 feet in height, extending over a space of four square miles, and sloping in all directions towards the plain; and, at that time, still in so heated a state that a cigar might be lighted, at the depth of a few inches below the surface, in any of the numerous cracks and fissures produced by the irregular and partial cooling.*

A subsequent eruption of this volcano took place in the year 1819, and was accompanied by an earthquake. On this occasion the ashes erupted fell in the streets of the city of Guanaxuato in such quantities as to lie six inches deep; although the distance of that city from the volcano is not less than a hundred and forty miles in a direct line.

The quantity of solid matter ejected during a great volcanic eruption, is not, however, the only way in which the internal fire changes the general level of the land. As an instance of this, the coast of Chili was visited by a very destructive earthquake in the year 1822, the shock being felt simultaneously through a distance of 1200 miles from north and south. On this occasion a line of coast, not less

* See the wood-cut at the end of this chapter.

than 100 miles in length was elevated above its former level, in some places three, in others four feet; and the change of level appears to have been permanent over an area of 100,000 square miles,—nearly as large as the whole extent of Great Britain and Ireland.

As another instance of a volcanic eruption, and one extremely remarkable for the extent of its influence, I may give, in a few words, an account of what took place in the island of Sumbawa (one of the Sunda islands, lying to the east of Java), in the year 1815. The noise of the explosions accompanying this eruption was heard at the distance of 970 miles to the west, and 720 miles to the east of the island. The ashes were carried 300 miles in the direction of Java, and more than 200 miles northwards towards the Celebes, in sufficient quantity to darken the air; and they were found floating in the ocean to the west of Sumatra, a distance of more than a thousand miles, forming a mass two feet thick, through which vessels with difficulty forced their way.

Having said so much of the effects of volcanic action in Asia and America, I will not add any detailed account of the well-known European volcanoes, Vesuvius and Etna. The former of these, Vesuvius, was first known as an active volcano about half a century after the birth of Christ, on which occasion the two cities of Herculaneum and Pompeii were buried beneath the ashes and mud thrown out; and from that time till 1666 several considerable eruptions are recorded to have happened, alternating, however, with long periods of tranquillity. For the last century and a half the mountain has been in a constant state of disturbance, and the periods of repose extremely rare.

Etna has been an active volcano from the earliest historic period, and has been remarkable for frequent and reiterated

eruptions, accompanied by torrents of lava; but the quantity of melted matter poured out on any one occasion has never been exceedingly great when compared with other volcanoes.

Perhaps the most remarkable eruption on record, in respect of the quantity of lava ejected, was that of one of the Icelandic volcanoes, the Skaptaa Jokul, in the year 1783. On the 8th of June in that year, the unfortunate inhabitants of the south coast of Iceland observed numerous pillars of smoke rising in the hill country towards the north, which gradually collected into a dark band, obscuring the light of day, and advancing in a southerly direction against the wind, showering down vast quantities of sand and ashes. The cloud continued to increase until the 10th, when fire-spouts were seen in the distance, and there were slight shocks of an earthquake. On the 11th the large river Skaptaa, which had lately been much swollen, entirely disappeared; and this accident was fully accounted for on the ensuing day, when a current of lava burst from one side of the volcano, and rushed with a loud crashing noise down the channel of the river, which it not only filled, but overflowed, although in many places the channel was from four to six hundred feet deep, and two hundred broad.

The fiery stream, leaving the hills, had its course checked for several days by a lake in the low country; but this also was at length filled up, and the torrent proceeded in two streams, one taking an easterly and the other a southerly direction. The lava continued to flow till the 20th of July, and following chiefly the course of the Skaptaa, it poured over a lofty cataract, filling up in a few days an enormous cavity, which the waters had been hollowing out for ages.

Up to this time the eastern part of the island had

escaped any more serious injury than the showers of ashes, which fell everywhere; but, on the 28th July, a further eruption was threatened; and, on the 3rd August, a thick vapour arising, and the waters disappearing from the bed of another river, the Hverfisfliot, prepared the inhabitants to expect a fiery torrent; which, accordingly, on the 9th, rushed on with indescribable fury, overflowing the country in one night to the extent of more than four miles, and converting their fearful anticipations into still more dreadful realities. The eruptions continued, at intervals, till the end of August, and closed with an earthquake of extreme violence.

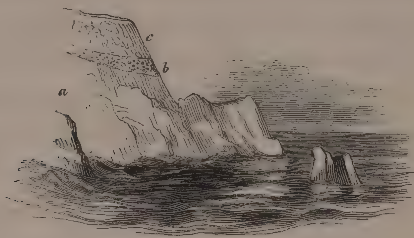
The immediate source, and the actual extent, of these torrents of melted rock have never been accurately determined; but the stream that flowed down the channel of the Skaptaa was about fifty miles in length, by twelve or fifteen miles in its greatest breadth, and that in the other river-course, about forty miles in length, by seven in breadth. With regard to its thickness, it was very variable; being as much as five or six hundred feet in the narrow channels, but, in the plains, rarely more than a hundred, and often not exceeding ten feet. Taking, however, the lowest average, and calculating the whole mass, it does not appear that there can have been less than twenty thousand millions of cubic yards, or forty thousand millions of tons of matter, poured out of the bowels of the earth, in a melted state, in the short space of ten weeks, during which the eruption lasted.*

* I cannot conclude the account of this fearful event without mentioning that, at the most moderate calculation, thirteen hundred human beings lost their lives during, or in consequence of, the eruption; and that it also involved the destruction of twenty thousand horses, seven thousand horned cattle, and one hundred and thirty thousand sheep. The fisheries on the southern coast of the island were destroyed; and Iceland has not to this day recovered from the disastrous events of the year of the eruption of the Skaptaa Jokul.

These accounts of a few of the more striking phenomena of recent volcanic action cannot fail to give some notion of the magnitude and extent of the deep-seated disturbing forces incessantly at work, tending to reproduce those irregularities of surface which are destroyed and levelled by the antagonist force of running water. But it must not be supposed that, in every instance, where a change of level is produced, and a tract of land elevated or depressed, the change was accompanied by an earthquake, or occurred in the immediate vicinity of a volcano. So far is this from being the case, that there is reason to believe in the existence of gradual and slow movements, by which a whole continent may be affected, in addition to these occasional outbreaks; and that the effects of such movements are to be traced along the whole of the southern and western coasts of the British Isles, and extend, also, throughout the North of Europe, producing a gradual elevation of the shores of the Baltic. Evidence of this is seen in various places along the coast, where the remains of sea-beaches are found, similar, in all respects, to those on the neighbouring shores; but which are now displaced, and, owing to a change in the relative level of sea and land, are elevated above high water mark often as much as forty or fifty feet.

The annexed diagram represents part of a raised beach which may be seen at Nelly's Cove, near New Quay, in Cornwall; and there may be observed at the point marked (*c*), a quantity of detritus, called a *head*, which has accumulated on the beach (*b*) since it was elevated to its present position; proving that the cliff which rose behind the ancient beach did not differ from that which rises above the present one. This head consists of angular fragments of the old rock (*a*); and shows that there has

been a considerable decomposition of this rock since the elevation of the beach, and, also, that there has been a movement of the decomposed surfaces of the hills partially covering up irregularities.



RAISED BEACH, NELLY'S COVE, CORNWALL.*

Along such a coast as that of Cornwall and Devon, the amount of change of level that would be required to elevate and expose these ancient beaches should also exhibit the beds of estuaries and sandy downs along the coast, similarly elevated. And this is precisely what we do find, for between Tor Bay and Charmouth, where the rocks on the coast are being rapidly worn away, beds are observed, in the valleys of the Otter and the Exe, which could scarcely have been deposited by the sea at its present level, and which yet contain marine shells common in the lower parts of the same valleys.

There is no reasonable way of accounting for the appearances of elevation, observable in those parts of the coast where raised beaches are common, but by assuming the existence of some deep-seated disturbing force, affecting the general level of the land. And such an explanation is the more probable, when we consider other appearances, often at no great distance, but which indicate

* Geological Report of Cornwall, Devon, and West Somerset, p. 431.

local depression of the surface, as clearly as the raised beaches do local elevation. It is not unusual, for instance, to find beds of vegetable substances occurring *below* the level of the sea; and these are so well-known along the South-western coast of England, under the name "Submarine Forests," and are so abundant, that Sir H. De la Beche remarks:* "it is difficult *not* to find traces of them in this district at the mouths of all the numerous valleys which open upon the sea." Now, as there appears to be satisfactory evidence that, in these forests, the roots of the trees are, in many cases, found in the situations where they originally grew, and as these roots are often to be traced as far as the lowest tides recede, we seem compelled to admit the conclusion before suggested, namely, that such changes have taken place by the elevation or depression of the land, which in the present instance must have suffered a depression, since the trees formerly lived on the spot where they are now submerged.†

But the submarine forests and raised beaches, so abundant in England, form only a limited portion of the whole number known to occur in Western Europe, and in all these cases the change of level has taken place since the vegetation upon the land, and the shelly inhabitants of the sea were of the same kind as we now find

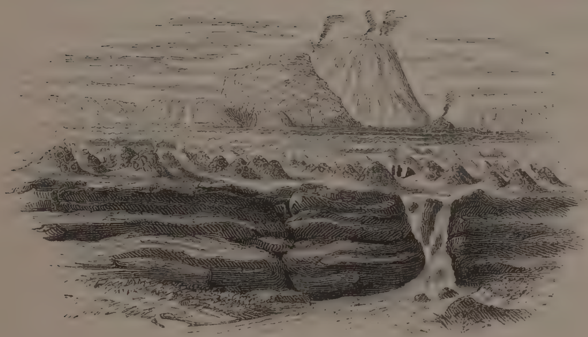
* Geological Report of Cornwall, Devon, and West Somerset, &c. p. 417.

† There might be supposed to be another way of accounting for these appearances, namely, a gradual advance of the waters of the ocean; but, even if such an hypothesis could account for one class of phenomena, as, for instance, for the existence of submarine forests, the explanation would be clearly insufficient and unsatisfactory, when we find, at no great distance, and along the same line of coast, that there are marks of the sea having formerly covered a spot which is now dry land. We can easily imagine that the land may have been by the same oscillatory movement, elevated in one spot and depressed in another, at no great distance; but to suppose that the waters of the ocean could rise permanently in one part of a sea, and be permanently depressed in another part, is a manifest absurdity.

them in the adjoining lands and seas. It becomes therefore clear to the Geologist, and will hereafter be proved to the reader, that the changes of level, to whatever extent, have been produced at a very recent period; and they must also have been gradual, and totally unaccompanied by those violent movements, which we are in the habit of thinking inseparable from the elevation or depression of a considerable portion of the solid crust of the earth.

It appears, then, that an examination of the phenomena of Nature, with reference to the causes at present in action, tending to modify the crust of the earth, introduces us to a series of changes, now going on, which can hardly fail to astonish those who are in the habit of looking upon the physical features of the globe as permanently, and even necessarily, fixed. It must also be evident that, if we find the earth's surface made up of a series of beds, each differing from the rest in mineral character, or in any other respect, and if these beds have been changed from their originally horizontal position beneath the sea, and now form dry land, there is really nothing in all these changes which differs, in *kind*, from others which have taken place under the immediate notice of man; however such phenomena may appear to be more remarkable, and differing in degree. And again, in those cases in which the strata are inclined, either slightly or at a high angle, and when they exhibit marks of having been burst asunder or displaced by great mechanical violence, and the intrusion of melted rock—not even then do we require to assume a cause which has ceased to act, and we have still only to institute a comparison between effects of a similar kind. Some degree of familiarity, therefore, with the present operations of nature on a grand scale, is of paramount importance to the geological

inquirer, and it is absolutely necessary for him to be aware of what is now going on, in order to be able to judge of the meaning of those past events with which Geology has to deal. It is only, indeed, by properly understanding the present condition of things that we are enabled to appreciate, and make use of, the evidence of former changes, and compare them with those of our own time.



VOLCAN DE JORULLO.

CHAPTER II.

TECHNICAL EXPRESSIONS.—VARIOUS KINDS OF ROCKS.—MECHANICAL EFFECTS PRODUCED IN STRATIFIED ROCKS.—STRUCTURAL PHENOMENA OF ROCKS.—NATURE OF POLAR FORCES, AND THEIR EFFECT IN PRODUCING GEOLOGICAL PHENOMENA.—GEOLOGICAL MAPS AND SECTIONS.

Having in the preceding chapter introduced the reader to a knowledge of the course of existing nature, I propose in this, to familiarize him in some degree with the language of Geology, or, in other words, to explain the most common of those technical terms and phrases usually employed in speaking or writing on the subject.

Now with reference to such technical expressions as form part of the language of science, I need hardly observe, that in every case where new ideas are to be communicated and discoveries or observations made in addition to those already on record, the person who desires to make an advance, must take up the subject where others have left it, and avail himself of all that has been done up to his own time. But, in order to do this, and to avoid the tedium of long description and frequent repetition, it is necessary, either that words already in use should be employed in a sense different from, and more extended than their known ordinary meaning, or new words must be introduced, peculiar at first to the particular science under discussion, and requiring to be understood before the science can become familiar to any one. The manifest disadvantage of having two different meanings attached to the same expression is the reason why, in all cases, the

latter method has been preferred; and each new word or phrase thus introduced may be looked upon as one of the steps made in the progressive movement of the science; and whenever the student familiarizes himself with the use of one of them, he too has gained a step, and is in a condition to advance with greater safety and greater certainty than before.

Technical language, indeed, resembles in this respect, any language foreign to our own, the idioms of which, as well as the words, must be felt and understood before we can fully comprehend certain styles of composition; and these idiomatic or technical expressions it is not easy to translate, as it is impossible to render with perfect accuracy the meaning of conventional phrases derived from local circumstances.

Cautiously avoiding, therefore, the use of words to which no definite meaning is attached, and explaining the sense in which I shall afterwards refer to those which are technical, I shall not hesitate to employ the most convenient term that may present itself, even at the risk of its being occasionally unfamiliar to the reader; convinced that if he can once be induced to take an interest in the subject, the apparent repulsiveness of these expressions will wear off, and his knowledge will be the more valuable and better retained by having been acquired with a little difficulty, and possessing proportionate definiteness and accuracy.

I have already alluded to the fact, that a very large proportion of all the rocks of which the superficial crust of the earth is made up, is deposited in regular layers or strata, of variable thickness and material, which are occasionally disturbed and even replaced by other rocks not bedded, but of crystalline structure and apparently of igneous origin. It is chiefly in consequence of movements effected in the former, or stratified rocks, by the action of subterraneous force,

whether accompanied or not by the intrusion of igneous rock, that certain changes both mechanical and chemical have been occasionally produced, with the nature and extent of which it is desirable that the reader should be acquainted before proceeding further in Geology. In this chapter, therefore, I shall consider the movements that have taken place among stratified rocks since their deposition, and the terms that are used by Geologists in describing the phenomena thus produced.

But first of all it may be useful to say a few words on the nature of the mineral contents of the different strata, and the extent to which we are enabled to carry our observations with regard to them. It is usual to designate all those substances which occur in masses, and which lie beneath the vegetable soil, by the general term *rocks;* and in this sense, clay and sand are called rock by the Geologist, as well as granite and limestone. Now the materials of which stratified rocks are made up, consist almost exclusively of variable proportions of sand, clay, and limestone, coloured with iron, and putting on the different appearances of stone or loose earth, of slate, shale, or tough clay, and of marl, chalk, common limestone, or marble, according to the peculiar conditions under which the formation has been made or exposed. A very slight knowledge of Mineralogy is therefore sufficient in the Geology of stratified rocks; and it is enough to be familiar with the ordinary changes of appearance and structure which silex (flint), argil (clay), and carbonate of lime (limestone or chalk), undergo when mixed with different proportions of oxygen and sulphuric acid, to recognise the prevailing character of any stratified rock.

The agency of heat and electricity (probably long continued), upon some of these rocks, has indeed, occasion-

ally, introduced changes in their internal structure and the arrangement of their particles amongst themselves, which present peculiar difficulties, and to which I shall especially allude before the conclusion of this chapter. At present, however, it will be enough to consider stratified rocks as made up of successive layers of sand and mud, and deposited from water, which had held them for some time in mechanical suspension or in solution.

There can be very little doubt that such quiet deposits from water must have been originally either horizontal, or so nearly so as to justify our considering them in that light. But, any one who examines for himself, either a coast line, or any other locality where a section of stratified rock is exhibited, will observe that, even where there is no other appearance of the action of subterraneous disturbing forces, the beds are tilted up and incline to the horizon, at an angle often far greater than that at which we must suppose them to have been deposited.

Now, when we multiply such observations, and connect together those made in different parts of England, it appears, that throughout the country the strata have a general inclination to the south-east, and, in spite of a vast number of local and apparent exceptions, we may correctly assert that, in travelling across England towards the north-west, we cross a long series of beds resting on one another, and all tilted in the same, or nearly the same south-easterly direction; so that as we advance, we are successively travelling upon those which are lower in the series, although very often they are at a higher elevation above the level of the sea.

In consequence of this peculiar arrangement of the strata, it results that we are enabled to obtain a knowledge of the structure of the earth to a very great depth; because

beds upon which thousands and tens of thousands of feet of strata have been gradually deposited are now elevated, and sometimes form the loftiest heights of our island.

And the explanation of this phenomenon is not at all difficult, nor need we be surprised at its frequent recurrence in every part of the world. Supposing the causes of those disturbances which produce earthquakes, and which raise or depress large portions of land, to be, as they must be, deep-seated, it is perfectly clear, that at every elevation the whole mass of the bed at the point of disturbance will be lifted, but that the upper portions alone will be exposed to the levelling action of the water. If, therefore, in time these lowest beds are raised above the level of the sea, they will not then be covered with the whole of the mass of rock which once rested upon them, but only with that portion which the waves and the currents have left.

As an illustration of the means we possess of judging of these earlier formed strata, over which so many others have been since deposited, let the reader place a number of books one upon another, and then overturn them in such a manner that each one except the lowest may rest partly on the volume beneath it, and with one edge on the table. Looking at the pile of books before they are displaced, it is clear that we can only obtain a knowledge of any one beneath the uppermost by removing those above it, and we can only know of the existence of more than one by looking at the whole series sideways, or in other words at a vertical section. But after they have been displaced, a mere examination of the surface is sufficient to give information as to the number of the books, their thickness and general appearance; and, although it is true that we cannot read the books through in this way, we can still learn something certain about them. Just so

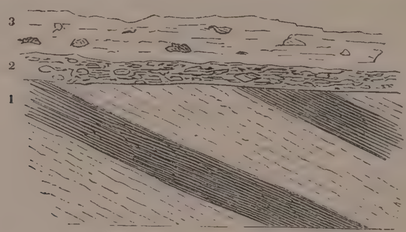
it is with the different formations or series of strata. Each group in succession has been deposited horizontally, but has afterwards, or during the time of its formation, been exposed to the action of subterraneous force, which has more or less disturbed the regularity of its position. The disturbances having taken place at irregular intervals, and the deposit going on constantly, we have thus many complicated phenomena introduced; but the forces having chiefly acted along certain lines, or at a point, there has resulted that regularity of arrangement, when the strata are examined over a large extent of country, to which allusion has already been made.

In order that the effects of these elevatory movements which are so universal, and so important, may be conveniently discussed and readily referred to, the words "*dip*," and "*strike*," have been introduced by Geologists; the former to express the inclination of a stratum, and the latter its direction. These terms are among the first that demand explanation; and although I do not imagine that any difficulty can arise with regard to their meaning, yet there are certain things to be observed in "*taking a dip*," as it is called, which require particular notice.

To take a dip is to observe the true direction of the inclination of a stratum at any point, and the amount of inclination to the horizon. Now, in order to do this, it is necessary to obtain not the direction of *any* line that may be drawn on the surface of the bed, because, however much a plane surface may be inclined, there will always be an infinite number of lines that can be drawn in it at various inclinations, and one which is horizontal; and the determination of this horizontal line which is, in fact, the strike, or the direction of the bed, is usually the best means of ascertaining the dip; for as the strike is the line of

intersection of the plane of the bed with a horizontal plane, the *direction* of the dip is necessarily at right angles to the strike, and its amount the angle which this direction makes with the horizon. Thus, in order to observe the dip and strike of a stratum, we first find by means of a spirit level, or by the eye, the direction of a horizontal line on its surface, and then measure the angle which a line at right angles to this makes with the horizon.*

It usually happens that several beds associated together have been affected by the same disturbances, the beds having been formed continuously and successively, while the elevatory or disturbing movements only took place after long intervals. When this is the case, and the strata succeed each other in regular order and uninterrupted



CONFORMABLE AND UNCONFORMABLE STRATIFICATION.

succession, they are said to be *conformable*, as are the beds of coarse gravelly stuff, represented in the diagram and marked (3), with the finer sandstones (2) upon which they rest.

* An instrument has been invented, called the Clinometer, for the purpose of taking geological observations of this kind. It consists of a compass provided with a small spirit level, and on the lid (which can be fixed at right angles to the compass box,) there is a small graduated quadrant, and a plumb line. But after all, a common pocket compass to determine the bearings, and a rule or even a walking-stick, to assist the eye in obtaining a level, is all that is needed in the ordinary field-work of the Geologist, because it is seldom possible to obtain more than a rough approximation of the real dip from a single observation, while, on the other hand, it is far more important to have the average of a large number of rough observations, than of a smaller number which are more minutely accurate.

On the other hand, the inclination of certain strata is sometimes so manifestly different from that of the overlying beds, [as in the diagram where the beds marked (1) incline at a high angle, but are overlaid by horizontal beds (2) (3),] that a displacement of the lower strata has clearly taken place before the deposition of the upper ones upon them. In this case the beds are said to be *unconformable*, or to lie unconformably upon each other.

It is one indication of the nature of those forces, by whose agency the strata lowest in the series have been occasionally brought to the surface, that a series of ridges is often observable, forming a striking feature in the physical geography of a country; and also of great geological interest, as marking at once the limits of one stratum, and enabling us to determine the "*outcrop*," or *basseting edge* of another.* Such ridges may often have been produced after the elevation of the bed, by the unequal action of water upon the alternating limestones and clays of which the beds are formed. They are usually spoken of in Geology as *escarpments;* and the escarpments of the chalk, of the different limestones of the oolitic series, and of the mountain limestone, may be readily traced on a map of England, and form ranges of high ground nearly parallel to one another, and having a general direction of north-east and south-west.†

In order to understand the nature of a large number of phenomena connected with the movements that have taken

* The word *outcrop* is commonly used to distinguish the line where the bed first appears at the surface, and ceases to be covered by a previously overlying bed.

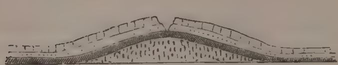
† The north of England abounds with magnificent escarpments of the mountain limestone, and in the west the escarpments of the oolites are both numerous and striking. In Wales, also, escarpments are not uncommon; and I have rarely seen a more picturesque or instructive instance than is exhibited at the back of the hill called Dinas Bran, near Llangollen, in North Wales. The mountain limestone

place in stratified rocks, and many expressions constantly recurring in geological descriptions, it will be worth while to assume for the moment a certain condition of the internal structure of the earth, and consider what would result *if* such had been the actual condition of things.

Let us assume then, not as a geological theory, but rather as a means of instruction, that, immediately beneath the external and solid crust of the earth, there is an intensely heated fluid mass, confined and kept within limits by the solid exterior ; and that, from time to time, this heated mass has forced its way to the surface, selecting, of course, a line or point of least resistance, which may originally have been produced by a crack or fissure, but where, the continuity being once broken, there must long remain a greater tendency to give way than elsewhere.

Taking this view of the cause of a subterranean movement, let us then trace its progress, and the effect it will have on the different strata that may happen to lie between the point of action of the disturbing force and the surface. The strata we must suppose to be of various degrees of hardness and tenacity, consisting, as strata usually do, of alternations of limestone, sand, and clay.

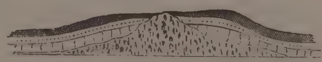
In the first place, if we suppose the upper bed to be hard, the middle one sandy and incoherent, and the lower tough and clayey, the effect produced will



be something like that represented in the annexed diagram ; and, if the force act at a point, a dome-shaped ele-

series is here beautifully shown, and the range of vertical cliffs, running in the direction of the strike of the beds, displays throughout the nature of conformable stratification in the most instructive and beautiful manner. The mountain limestone is here also totally unconformable to the older (Upper Silurian) strata of Dinas Bran.

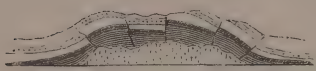
vation will be produced, the beds inclining in all directions equally from the top of the dome. If, however, the force act along a line instead of at a point, the effect will be different, and instead of a dome, what is called an "*anticlinal axis*" will be produced—an appearance like that of the roof of a house, or of a saddle, the beds dipping in opposite directions from a line which is in the direction of the disturbing force.* If the beds had been arranged in a different order, the general effect would still have been the same; but the igneous rock, bursting through the brittle or incoherent beds, might have appeared as a boss on the surface, after that the action of water had carried away a portion of the upper softer beds.



But, although an effect like that just described would undoubtedly be produced when there was no very great or unequal resisting power, there would be a somewhat different effect if the force were to act over a large exposed surface. In this case, the edges of the beds being, as it were, tied down by the pressure of the superincumbent strata on all sides, there would be produced a series of parallel, or nearly parallel, cracks, and a number also of cross fissures, or cracks at right angles to the principal ones. There would also be an elevatory movement proportioned to the magnitude of the disturbing force. If this were considerable it would be accompanied by a vast multitude of cracks, and as soon as the disturbing force was removed and equilibrium restored, the force of gravity would begin to act, and the various

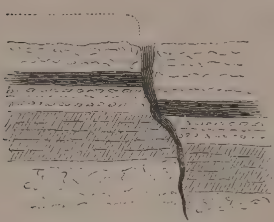
* The expression "*synclinal axis*," or "*trough*," is also frequently used to express the converse phenomenon,—namely, when the strata dip *to* such a line instead of *from* it. Between two anticlinal axes there must therefore be a synclinal axis.

fractured portions sink irregularly, either filling up the cavity left, or forming a natural vaulting; the continuity of the strata in either case being completely broken, and presenting an appearance such as is sketched in the diagram.



Now, such a discontinuity of the strata is a phenomenon exceedingly common in all stratified rocks, and especially in those low down in the series, or which occur in hilly districts, and it is commonly spoken of in Geology as a *Slip* or *Fault*.

The meaning, then, of the expressions, "fault," "trouble," or "slip," when used in Geology, is, that one portion of a stratum has been broken away from the rest, and has been displaced, being elevated or depressed sometimes to a considerable distance. A simple fault, as seen under ordinary circumstances, is represented in the accompanying diagram; where a dotted line marks a portion of the upper bed, which has been removed since the elevation, leaving the general surface without any external proof of the elevation that has taken place on one side of the fissure. The strata are here represented as separated by an interval, which is usually filled up with rubbish, and the sides, which were formerly in contact, are not unfrequently polished, and marked with lines or striæ, by the friction of the beds against one another. This polished appearance is well known to miners and in mining districts, and is called *slickensides*.



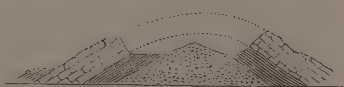
EXAMPLE OF A FAULT.

Faults occur in rocks of all ages, and vary in magnitude indefinitely. The amount of displacement is sometimes only a few inches, sometimes several hundred fathoms; the extent in direction may be a dozen yards, or very many miles; and the space between the fractured edges of the beds is almost imperceptible in small faults, while it is occasionally filled up by thick walls of igneous rock poured into the fissure in a melted state. In this latter case the fissure, with its contents, is called a "Dyke."

I have already mentioned that the portion of a series of strata which, during the formation of a fault, has been elevated above the general level of the surface, is sometimes swept away, and leaves no vestige of the disturbance. This clearing away of the effects of a subterranean movement from the surface is not, however, confined to the case of faults, but is also common when an anticlinal axis has been formed, the softer beds being washed away, and leaving sometimes the lower strata occupying a valley enclosed by the harder rocks, which were originally superimposed. The process by which these portions are removed is called *denudation*, and is one of which the Geologist has frequent occasion to speak. When a valley is formed simply by the sweeping away of a portion of strata, regularly bedded and undisturbed, it is usually called a "*valley* of *denudation*;"

SECTION ACROSS A VALLEY OF DENUDATION.

but when, in consequence of some subterraneous movement, the lower bed is in a hollow, and is surrounded by hills of the upper strata, dipping away in all directions from it, there is then said to be a "*valley of elevation*."



SECTION ACROSS A VALLEY OF ELEVATION.

Having now defined those terms most commonly made use of in Geology, which have reference to the action of disturbing forces, it becomes necessary to notice in the next place certain appearances in the structure of stratified rocks, which require for their explanation the action of some other force than that of gravity, and which may rank amongst the most difficult, though at the same time the most interesting, problems at present under consideration in Geology. These appearances are strikingly exhibited in rocks of slaty texture.

Roofing slate is a mineral perfectly familiar to every one, and to acquire a knowledge of its structure may, at first sight, appear to be a matter of no peculiar difficulty. When examined, however, in a quarry, and on a large scale, this slate is found not to be stratified in the usual sense of the word, but to be affected by three kinds of stratification, in different directions, and independent of one another. Of these three kinds, one corresponds with ordinary bedding; and its direction may sometimes be traced by the remains of shells or other organized bodies; which, however, are frequently absent, and the true bedding very obscure. Another kind is called by Geologists *cleavage*, and is the cause of the great facility there is of splitting the slate; while the third kind scarcely resembles stratification at all, but consists of a tendency in the rock to separate into solids, of definite shape and proportions,—the places at which this tendency shows itself being called *joints*, or *divisional planes*. These two latter phenomena of joints and cleavage must now occupy our attention for a short time.

Cleavage is a peculiar structure sometimes superinduced in argillaceous rocks, by which the particles of the rock become completely re-arranged in planes parallel to one an-

other, and without any reference whatever to the original stratification (which, indeed, is sometimes obliterated by the change); the resulting mass being infinitely divisible in the direction of the cleavage planes. In consequence of this semi-crystalline structure, it would seem not improbable that a process has taken place analogous to that of crystallization, either caused or aided by weak, but long continued, chemical and electric action.*

The difference between cleavage and joints is this: when a rock is only affected by the latter structure, the portion between two of the divisional planes has no tendency to cleave in a direction parallel to them; whereas a rock affected by slaty cleavage will be capable of infinite subdivision in the direction of the cleavage planes.

Joints are defined to be natural fissures, traversing rocks in straight and well-determined lines, forming planes of separation, often slightly open, and passing not merely through strata, but through various semi-crystalline aggregations, evidently formed since the original accumulation of the strata.

Numerous observations, made in various localities, with regard to the direction which these fissures take, have already led to interesting results; and the continued attention

* An experiment made by Mr. R. W. Fox seems to favour this idea. Mr. Fox submitted a mass of moist clay worked up with acidulated water, to weak voltaic action for some months; and it was found at the end of that time, to exhibit when dry a rude laminated structure, the planes of the laminæ being at right angles to the electric forces.

A fact also observed by Mr. Darwin, induced that gentleman to believe, that slaty cleavage can be superinduced when considerable chemical action takes place in fine mud; and as true slaty cleavage only occurs among those strata which are in the immediate vicinity of igneous rocks, or of great fractures, it is not unlikely that, although the direction of the cleavage may have some dependance upon electrical action, the agency of heat may have assisted in producing movements in the particles of an amorphous mass, which terminated in the structure of a schistose rock, where the appearances of aqueous deposition are obliterated.

of Geologists to this subject will probably, in time, become the source from whence many interesting generalizations may be deduced. As an instance of such observations, and of the importance of multiplying them wherever there is opportunity, I may mention that in a very large majority of cases, the joints in the mountain limestone districts in the north of England, in Derbyshire, and in parts of Ireland, have either a direction varying but little from N.N.W. and S.S.E., or a direction at right angles to that; and out of eighty-nine observations made by Mr. Phillips in Yorkshire, fifty-five of them exhibited the joints varying between N.W. and S.E., and N. and S.; twenty-eight were at right angles to these; and there were only six which deviated to any considerable extent from this apparently general law.

It appears then, that in addition to the mechanical disruption of strata, there are other phenomena relating to stratified rocks, having apparently no reference to stratification, or to the original circumstances under which the rock may have been formed, and not to be accounted for by any external agency, but belonging to the action of forces of a different kind, which have produced, to a greater or less extent, a re-arrangement of the particles of which the rock is composed, and a tendency to crystalline arrangement on a large scale. The kind of force thus brought into action is quite peculiar; and although not of a nature to be very clearly comprehended by the general reader, well worthy of being considered with some little attention, if only with a view to its bearing upon phenomena strictly geological.

The most simple idea of the nature of such forces is derived from a consideration of the polarity of the magnet, and from the fact, that when a current of electricity is

made to pass through a metallic needle freely suspended, the needle acquires a tendency to exercise certain elective attractions, (the magnetised body attracting or repelling, as if by choice;) and also to place itself parallel with an imaginary line passing through the earth between two points near the poles of the earth. This condition of the needle is called polarity.

But the study of crystallography, and the known influence of electricity in producing a crystalline structure, indicates a further relation which could not have been anticipated; and induces the Geologist to seek to become more minutely acquainted with a force which differs so completely from the force of gravity as *not to act alike in all directions* upon the particles exposed to its influence, but which, nevertheless, is known to act extensively and powerfully in nature. Whatever it may be, it is at any rate quite certain that there is a force which can be brought into action by the agency of heat and electricity, and which gives to the internal constitution of solid bodies in the act of crystallization certain remarkable properties; enabling them, for instance, to resist compression with different degrees of elastic force, according to the direction in which the compression is exerted. It also affects their structure in such a way, that the perfectly crystallized body splits readily in certain directions, and not at all in others; and when broken into the smallest fragments it presents glittering plane surfaces, making fixed angles with one another, and allowing the crystallographer to decide, by the mere measurement of these angles, the nature of the fragment before him.

The existence, in this way, of a force, tending in certain cases to bring together and keep in their places the particles or atoms of solid bodies under conditions totally dif-

ferent from those by which masses of matter are brought together by the attraction of gravitation, seems to involve the idea of attractive and repulsive forces of a peculiar kind. To the action of such peculiar forces, the ordinary phenomenon of the polarity of the magnet must be referred; but this is only one of a large class of facts, indicating important modifications of laws, which we are in the habit of regarding as of universal application.

The circumstances, under which this law of polarity will begin to act upon an aggregation of particles in mechanical contact, are not at all well understood; but it cannot be doubted that the particles tend to arrange themselves according to such law, even at the ordinary temperature, and in strata recently formed by deposition from water. There can be little question that both cleavage and divisional planes or joints are structural phenomena, dependent on the action of these polar forces; but we have yet to discover the true nature and extent of electrical influence in effecting such changes, and the mode in which the influence is exerted.

We have been considering, in this chapter, the effects which would be produced upon the superficial crust of the earth, supposing it to have been made up of a series of strata deposited from water, and disturbed from time to time by violent mechanical force acting from below, the force being sometimes sufficiently powerful to fracture the strata, and give vent to the molten mass beneath, but at other times only tilting and displacing the beds, without appearing at the surface. The method which I have here adopted, of explaining certain appearances, may seem perhaps, at first sight, to require the acceptation of the theory introduced to account for them. But such is by no means my intention, and in making use of this method, I

have merely wished to avail myself of a convenient way of bringing the phenomena before the reader in a tangible form. Whatever may be thought of the theory, the phenomena themselves are real, and it is an unquestionable truth that the surface of the earth is made up of strata, which, if they were not deposited horizontally, and placed in their present positions by the exertion of great mechanical force, were deposited in opposition to the general laws by which nature is governed.

It is also true that there are many thousand feet of stratified rocks laid open for examination, each stratum being occasionally affected by peculiarities of dip and strike and of conformable and unconformable stratification with the underlying and overlying beds. Each also is affected by systems of faults which do not affect the superimposed strata; and which must be considered in relation to one another, as well as separately. We shall see hereafter that each is marked by an additional peculiarity, namely, by the presence of animal and vegetable remains characteristic of it, and differing sufficiently from the remains found in other beds to distinguish the stratum, even when the mineral composition is not the same.

Before concluding this chapter of definitions, however, I must add a few words on the method employed to communicate a knowledge of geological facts in the most convenient way; and the nature of the illustrations,—the geological maps and sections,—which offer the most simple and instructive means of registering any information that may be acquired of the geological structure of a district.

When a Geologist desires to record or communicate his observations on a new country, he does not consider it sufficient to give a verbal account, however copiously

detailed, but he accompanies his description with a geological map and sections; and these, in fact, comprise the general result of his researches. The same means are not less useful or necessary in imparting to the student a detailed knowledge of formations, and they must always be extensively employed in descriptive Geology.

A geological map is a map in which not only the ordinary physical features of the country are indicated, but a number of colours, or markings, are employed to distinguish the different strata, or groups of strata, that would appear on the surface, if the superficial coating of vegetable soil were removed. The line between two colours marks the outcrop of the underlying stratum, and the direction of this line represents the strike. The amount of the dip not being given, no idea can be formed of the thickness of the formations; nor are the disturbances indicated, except by the occasional appearance of igneous rock penetrating through the strata. A good map of this kind represents the results of a number of observations at points not distant from each other, being the observations made at all places where a knowledge of the structure can be obtained, whether by quarries opened or wells sunk, by a road across a hill or a stream in a valley, or any other natural or accidental means that there may be of penetrating below the coating of soil or gravel. Such a map being projected, it is found the best way to note down first any marked differences of structure which the physical geography of the country may indicate, and after that proceed to record more detailed observations. This method of making use of the first rough notes is the more useful, because important general views are not unfrequently suggested by them; and a theory starts up which serves as a useful guide and a source of inquiry in further re-

search, provided, of course, that it is only made use of in that way, and is readily abandoned or modified if subsequent observation should be found not to support it.

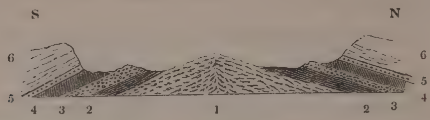
A map, however, without accompanying sections to explain and interpret it, is of comparatively little value; as the object of the sections is to teach something of the internal structure, in addition to that knowledge of the surface, which is all that the map can convey.

The natural sections of strata observable in the cliffs along a sea-coast, and other similar cuttings made artificially through a hilly country, form but a very small and unimportant part of the sections upon which the Geologist depends for information, although they offer, perhaps, the best specimens of the actual meaning of the word. It is in fact, not at all indispensable to have an actual cutting in order to draw a useful geological section; and it becomes, therefore, necessary to explain the real nature of the sections most commonly obtained. This is best done by means of an example.

Let us suppose a Geologist to start from the chalk cliffs of Brighton, on the south coast of England, and to travel northwards towards London, with a view of making himself acquainted with the geological structure of the intermediate country. He would first observe, that, at Brighton, the chalks* (6) dip moderately to the south, and crossing the Downs, he would reach, in the valley at their foot, a bed of sand (5), having the same dip as the chalk, and evidently lying under it. Sketching approximately the outline of the country, he would then, by lines, or some convenient mode, indicate the conformability of the beds, and the result of this first observation. Passing on northwards he would find the dip constant, but the sand would

* See the diagram, p. 46.

soon give place to a thin bed of clay (4), and that again to a thicker and harder sand (3), and another clay (2), but of



SECTION ACROSS THE WEALD, FROM THE SOUTH DOWNS, TO THE SURREY HILLS.*

different appearance. Each of these facts he would notice, and mark down in his section by some appropriate sign; and when he had thus passed over these five different beds he would find a sixth, different from any of them, consisting chiefly of sand (1), and at first having the same southerly dip as the other strata. The sand he would trace over a considerable extent of country, rising into a ridge of hills of some height, the dip increasing and becoming doubtful towards the central ridge, until at length it appears nearly vertical, and then changes and inclines to the north, indicating that an anticlinal axis has been crossed. As he advances still northwards, our Geologist would find this northerly dip to continue; and at length the sand would be covered up by a clay, also dipping north, and resembling the clay covering the sand on the south side. This clay is succeeded by sandstones and another clay, the order of deposit being the same; but, in consequence of the inverted dip, the strata successively covering up those which have been passed instead of rising up from beneath them. The wood-cut in this page represents all these phenomena in the order in which they occur, although there is no attempt at giving

* 1. Hastings Sand. 4. Gault.
2. Weald clay. 5. Upper Greensand.
3. Lower Greensand. 6. Chalk.

any idea of the comparative extent of the beds, the lower bed of sand occupying a much greater space in proportion to the whole than is represented in the diagram.

It is also to be observed, that for the sake of marking certain changes and facts of interest in a more striking way, the Geologist frequently exaggerates very much the differences of altitude in a section; or, in other words, he selects a scale for heights many times greater than that for distances. This plan is not altogether without disadvantage, as it often gives a false notion of the amount of dislocation in a mountainous and disturbed district; but on the whole, the advantage gained by bringing all the important peculiarities of structure before the eye seems to be of more importance, and the method is therefore commonly resorted to.

It is not upon the evidence of a single section only that any important generalization in Geology is made to rest. Numerous sections across the strike of the beds, and more or less nearly parallel to one another, must always be made and considered in their mutual bearings; and in selecting a line along which to observe a section, it is necessary to bear in mind, that unless it is in a direction at right angles to the strike, it can only give imperfect notions of the real condition of the strata. In preparing a section, also, any fault that exists, and can be determined, should be marked; and when the beds are unconformable this also must be noted, every point of detail being, in fact, introduced, and always as nearly as possible as it occurs in nature. But here, as in the observation of dips, extreme accuracy in a single instance is frequently a waste of labour; and the time would be far more usefully employed in making a number of approximate observations, from the average of which a result more really accurate may be deduced.

In all geological investigations, indeed, it should be remembered, that whatever be the nature of the phenomena observed, they are not isolated, but belong to, and are connected with, innumerable others; and that, therefore, the nature of this relation being the ultimate object of the science, it is not so much minute detail at a particular point that is valuable, as the careful observance of the general bearing of all these details on the structure and disturbances of strata or formations.

HONISTER CRAG.

CHAPTER III.

THE NATURE OF FOSSILS AND THEIR VALUE IN GEOLOGY.—PALÆONTOLOGY, AND THE IMPORTANCE OF A NATURAL CLASSIFICATION OF ANIMALS IN THAT SCIENCE.—CUVIER'S METHOD OF CLASSIFICATION IN ZOOLOGY.

Stratified rocks having been formed, for the most part, by the action of water, and from substances held in mechanical suspension by water, frequently contain the remains of animals which inhabited the sea at the period of the formation of the bed, and occasionally also of vegetables and land animals living in the neighbourhood of rivers, and transported by them into the ocean. The extent to which these remains occur varies much in different strata, partly, no doubt, according as the mineral composition of the stratum is more or less favourable for their preservation, but partly also as the circumstances of the deposit were adapted or not to the existence of animal life.

Such remains, of whatever kind, and in whatever condition, are commonly spoken of as "*fossils*," or "*organic remains*." They are met with in almost every stratified formation, and are sometimes admirably well preserved, being often indeed changed from their original condition, but in such a way as to retain their peculiarities of form and structure. They are different in different formations; and even looking only at their general appearance, they evidently indicate a wider departure from the forms of existing animals and vegetables, as those fossils are examined which are taken from the rocks lower down in the series. The remains most commonly met with being

those of marine animals, and consisting chiefly of corals, shells, &c. the actual marine origin of an extremely large proportion of all the rocks which now form the surface of the earth is distinctly proved; and we are led by the examination of fossils to a knowledge of the fact, that all those vast thicknesses of strata were formed by a slow and gradual process at the bottom of the ocean. It is in this way that the study of organic remains introduces an absolute necessity for the assumption of long periods of time in the production of geological phenomena,—a statement which has so frequently startled many persons, who have not considered the subject in a proper light.

I do not here propose any theory or attempt any explanation on this subject, and I merely express an unquestionable fact when I assert that the very numerous strata of which the crust of the earth is made up were formed gradually; that each of them occupied a long period of time (by which I mean not years but ages); and that to this conclusion no one, who makes use of his intellect, and allows himself to come to the consideration of geological facts with an unprejudiced mind, can help arriving. And this conclusion I call a fact, and not a mere opinion, because it rests on evidence quite as strong as it is possible to have on any subject; and if we are not to believe in the evidence of our senses, when that evidence is weighed and supported by the best exercise of our judgment, we can evidently believe nothing. If indeed we are allowed to assume, that because a conclusion fairly arrived at is contrary to a preconceived notion, it is therefore to be thrown on one side as false and worthless, what are all our other conclusions worth?—what is the foundation of our belief?

But it may be said, how do we know that the lapse of a long period of time is so necessary? This question will

be answered in detail in the ensuing chapters: but, as a general answer, the fact of the abundant existence of fossils is sufficient; and the nature of the argument thus brought to bear upon the question it is at present my object to show.

The fossil remains of animals and vegetables have been usually more or less changed in their internal structure, and mineralised during their long abode in the strata in which they are preserved: the way in which this has been effected varied as the circumstances were different.

One of the most common methods by which corals, shells, &c., and even bones, have been preserved, is by the simple abstraction of the more corruptible parts; the salts of lime, which formed the original skeleton, being left almost without change.

Another, perhaps equally common, and more complicated process, is that by which the animal or vegetable remains have been embedded, before decomposition has taken place, in some clayey or muddy accumulation; and the substance having, under these circumstances, decomposed slowly, the particles have been replaced, atom by atom, as they were given off, by corresponding particles of some mineral, (as silex, or carbonate of lime,) until at last no part of the original is retained, although every point of structure is so accurately exhibited, that the fossil is, in all respects, as valuable and instructive as the very animal or vegetable itself. This process is sometimes still further complicated; as, for instance, in the numerous flints from the upper chalk, in each of which there may be found embedded the remains of some spongy zoophyte. In these cases every particle of the fossil has been replaced by a particle of silex, but the whole, at the same time, is embedded in and surrounded by silex, and so intimately united with it, that it is only by the

appearance of structure that we can at all determine what part of the flint represents an organized body, and what part merely encloses it.

By a third process of fossilization, of which the effects are frequently seen, the remains of organized bodies form part, and often not an unimportant part, of the entire substance of certain limestone strata, the fossil being occasionally crystalline in its structure, and, in this respect, differing from the surrounding rock. Many of the common building stones used in England exhibit this peculiarity; and the beautiful marbles of Derbyshire and Devonshire are thus often loaded with fossils, and sometimes entirely made up of them.

Besides these instances of the way in which the minute internal structure of animals and vegetables has been preserved, there are found in all formations a number of other fossils, which represent only the form, whether external or internal, of that which was once organic, but retain all the markings of whatever kind, with the accuracy of the most perfect model. Such casts or models of the actual substance deposited are often of great interest and extremely useful, and are sometimes sufficient even to identify species where no other means of comparison are at hand.

The casts most abundantly found are those in which an impression of the external surface of a shell, coral, or other organized body is communicated to the clay, limestone, or sandstone of the rock in which the fossilization has taken place, and the substance itself then decaying, either partially or entirely, the space thus left has been, in the course of time, filled up by mineral particles which have formed a more or less perfect model of the original organised body. In other cases, the softer parts of an animal or vegetable decaying, have been replaced by mineral matter,—the

whole has in this state been embedded in some deposit, and after a time the harder parts have also decayed, leaving an internal cast, whose *exterior* offers a representation of the *internal* surface of the body. It happens too, occasionally, that a natural cast is taken of the whole of the internal structure of an organized body, which is thus represented in a very singular way,—the parts now solid occupying what were once the hollow interstices between the particles of animal or vegetable tissue.

In a word, there is no limit to the number and variety of these remains of animal and vegetable existence. At one time we see before us, extracted from a solid mass of rock, a model of the softest, most delicate, and least easily preserved parts of animal structure; at another time the actual bones, teeth, and scales, scarcely altered from their condition in the living animal. The very skin, the eye, the foot-prints of the creature in the mud, and the food that it was digesting at the time of its death, together with those portions that had been separated by the digestive organs as containing no further nutriment, are all as clearly exhibited as if death had within a few hours performed its commission, and all had been instantly prepared for our investigation. We find the remains of fish, so perfect that not one bone, not one scale, is out of place or wanting, and others, in the same bed, presenting only the outline of a skeleton, or various disjointed fragments. We have insects, the delicate nervures of whose wings are permanently impressed upon the stone in which they are embedded; and we see occasionally shells, not merely retaining their shape, but perpetuating their very colours,—the most fleeting, one would think, of all characteristics,—and offering evidence of the brilliancy and beauty of creation at a time when man was not yet an inhabitant of the earth, and

there seemed no one to appreciate beauties which we are, perhaps, too apt to think were called into existence only for our admiration.

These are a few instances selected from the almost innumerable evidences of the former existence of animated beings upon the earth; and such animated beings were not identical, although often analogous to those now living, as it is found that in each stratum there are species characteristic of that particular bed, differing from the species of similar animals or vegetables in other strata, or now living, and offering very frequently a means of identifying formations, which is the more satisfactory, because entirely independent of the mineral composition of the beds.

This important statement, however, that "fossils are characteristic of formations," supposes a certainty in the determination of species by the fossil remains handed down to us, and a degree of perfection in the application of Zoology and Botany to such fragmentary portions of structure, that the reader may fairly require some account of the successive steps by which the result was at length reached, and a connected view of the nature of the argument that has led to conclusions which, however viewed, are so exceedingly remarkable.

The branch of Natural History which treats of the animals whose remains have been found embedded in the various strata of which the earth's crust is composed, has become of so much importance within the last few years as to render it convenient to employ a new name, PALÆONTOLOGY, in speaking of it. The name, which means, literally, an account of beings who lived long ago, sufficiently describes the nature of the science; and in this sense, as a rational account of the natural history of species of animals not known to exist in a living state, it may be said

to have been founded by Cuvier, and to date from the publication of those remarkable memoirs, prepared by him from time to time, on the subject of the organic remains discovered in the gypsum beds near Paris, and afterwards collected and re-published under the title "*Recherches sur les Ossemens Fossiles*." The task thus accomplished, the nature of the labour and the difficulties that were to be overcome, are so admirably described in the introduction to the "Ossemens Fossiles," that I cannot do better than give, in a translation, the words of the great naturalist himself.

Alluding to the fossil bones under examination, he observes: "An antiquary of a new kind, I had at once to restore these monuments of past revolutions, and to decipher them. I had to gather together, and to arrange in their original order, the fragments of which they were composed; to reconstruct the ancient forms to which these fragments belonged; to reproduce them in their just proportions, and with their proper characteristics; and when I had done so, it remained for me to compare them with animals living now upon the earth. This was an art at the time almost unknown, and assumed those laws of analogy, and of the natural dependence of one part of the body upon all the rest, and the general harmony of the whole, which, up to that time, had scarcely been contemplated as existing."

In was in fact impossible that any great step could be taken in Palæontology without a minute acquaintance with the comparative anatomy of existing species, and an accurate knowledge of the relative importance of each part of the skeleton of an animal, and of each organ, together with the bearing of each on every other part, and on the whole. Preliminary knowledge of this kind was absolutely necessary, and it led the way to a new system of classification in

Zoology, founded upon extensive observation, and whose object it was to be simply a transcript of nature. It was to his perfect knowledge of comparative anatomy that Cuvier trusted in his endeavour to form such a system; it was in analogies which he found to exist throughout all nature, that he laid the foundation of his great discoveries; but above all, it was his caution, his accuracy of observation, and his firmness in following steadily every peculiarity of structure, until he had fully made out its exact value in the animal economy, that enabled him not only to lay the foundations of a science, but to pursue it almost to perfection.

As, therefore, Palæontology is but a branch of Zoology, and the arrangement of animals no longer existing upon the earth is closely interwoven with the history of living species still common, it becomes desirable, and even necessary, before considering the analogies, by means of which zoological knowledge is brought to bear upon extinct species, that the geological student should have a clear notion of that natural order of classification which has been of such extreme use in advancing our knowledge of Palæontology.

It cannot require any argument to prove, that in a science, such as Natural History, which is almost entirely descriptive, a methodical arrangement and system of classification is of the most vital importance, and that the principle of classification should be, to discover, if possible, some peculiarity of habit or structure, so that, in each species, its position in the system, and the name by which it is recognised (if already known), should be at once distinctly made out.

Before the time of Cuvier, however, all systems of zoological arrangement had been founded on external characters to the exclusion of internal structure, and were

thus dependent on arbitrary principles. And such systems, although to a certain extent natural, and really founded on peculiarities of structure, were partial and unsatisfactory, inasmuch as they were derived from partial and limited views of nature and from imperfect knowledge. It was by considering not only particular organs, or parts, of an organized being, but the whole structure, and by comparing not only animals nearly alike, or greatly unlike, but all known species, that this great work of a natural classification could be accomplished.

Cuvier, by a happy combination of patient research, extensive knowledge, and clear and active intellect, aided by fortunate circumstances, succeeded in laying the foundation of such a system on the basis of comparative anatomy; and whatever faults of detail there may be in the superstructure he has reared, it must always be looked upon as a work of the highest merit, and of the most real utility in its effects on the progress of science.

The general outline of this method I now proceed to explain; and not forgetting the main object I have in view, the application of Zoology to Palæontology, I shall dwell more particularly on those subdivisions and groups which will chiefly be referred to in future descriptions of fossil species.

There are certain great divisions of natural objects, so decidedly marked by nature, and offering such broad distinctive characters, that no great amount of observation is required to discover them. Such, for instance, are the divisions into the Animal, Vegetable, and Mineral kingdom of all the vast multitude of natural objects of which we have any knowledge; and such also is the division of the animal kingdom into *vertebrated* and *invertebrated* animals; under the former name, including those provided with an

internal frame-work, or skeleton, attached to a vertebral column, or back-bone, through which the spinal marrow passes from the brain; while on the other hand the invertebrata have no such skeleton, and the nervous system, instead of being centred in one brain, is collected into several lumps (called *ganglia*) in different parts of the body.

The vertebrated animals, again, are readily divided into four great classes: MAMMALIA (or those which suckle their young), BIRDS, REPTILES, and FISHES; and the anatomical characteristics of each are derived chiefly from the locomotive organs, as the extent of the developement of these is dependent on the organs of respiration and circulation.

It is not so easy to subdivide the invertebrata. They were separated by Cuvier into three classes: MOLLUSCA, or soft animals, many of them covered with shells; ARTICULATA, animals with distinct articulated limbs, such as lobsters, &c. insects, and worms; and RADIATA or ZOOPHYTA, a miscellaneous class, including a vast multitude of species possessing few analogies with one another, and which have since been subdivided into two groups, chiefly from peculiarities of the nervous system. The sea urchin and the numerous tribes of polyps, and of infusorial animalcules, may give an idea of some of the animals referred to in this class.

It is after these larger groups have been determined that the true difficulties of classification commence, and that the knowledge and judgment of the comparative anatomist is required to decide in which subdivision certain species shall be placed, when they seem to possess the peculiar characteristics of more than one group. There are two steps in arrangement easily made,—the first is that of forming large natural groups, few in number, and very

comprehensive; and the other is the actual determination of species,—but between these two a considerable number of intermediate arrangements are necessary; and each division, as it includes a greater number of species, should express some distinctive mark, more important, more characteristic, and more visible, than any one of lesser generality.

The nature of the classification proposed by Cuvier will be best understood by considering, in some little detail, the subdivisions of the more highly organized or vertebrated animals. The reader will thus be enabled to form an idea of the system, and to appreciate the value of the argument deduced from it and applied to extinct species.

The MAMMALIA, the first of the four great classes, into one or other of which all vertebrated animals are grouped, contains those species in which there is a complete double circulation, the whole of the blood being transmitted from the heart to the lungs, and received back into the heart before it is in a state to circulate through the system. All the animals of this class are brought forth alive, and are nourished by milk secreted by the mother, until they are able to seek their own food.

The Mammalia are divided into nine orders, characterised (1) by the structure of the extremities, on which depends much of the activity, and many very important habits and peculiarities of the animal, and (2) from the organs of manducation, or the teeth and jaws, which determine the nature of the food, and are intimately connected with every thing relating to the function of digestion, and a multitude of other differences, including even those which have reference to the developement of the intellect and the instincts of the animal.

There are two very decided differences in the structure of the extremities of Mammalia; for these extremities may

either, as in man, be expanded into hands, terminated by fingers, which are defended on one side by a nail, and are delicately sensitive on the other; or, as in the horse, the leg may be terminated by a foot contracted into a hoof, which completely envelopes the toe, and is incapable of being used as an organ of touch. This great distinction was made use of by Linnæus, who divided his class of "Quadrupeds" into *unguiculata*, or animals provided with fingers and claws, and *ungulata*, or hoofed animals.

Again, the form of the teeth, and the corresponding articulation of the jaw must, in a great measure, determine the nature of the food which an animal eats; as for instance, sharp teeth, which meet and lock into each other like scissors, with a vertical motion, are only adapted to cut and tear flesh. Animals, unprovided with such organs, on the other hand, and whose teeth are flat topped, and their jaws provided with a lateral motion, could not exist at all if their extremities were not organized so as to obtain a sufficient supply of vegetable food, and their stomachs to digest it. There are several modifications in the structure of the teeth and the motion of the jaw, upon which important distinctions are founded, and it has been discovered that even differences so minute, that they can only be observed by the aid of an excellent microscope, correspond in a most remarkable way to other differences, either in structure or in the habits of the animal; and may be depended on as indicating such differences, even in the absence of every other part of the skeleton.

I. The first order of Mammalia includes but one species, Man, the order being named Bimana, or two-handed, because man is the only animal provided with true hands at the anterior, and feet at the posterior extremity. This structure of his extremities enables him to obtain, and that of his

teeth to masticate, all kinds of food; and he is, beyond all other animals, possessed of the greatest variety of powers, and the greatest degree of adaptability to change of circumstances, whether of temperature or food.

II. The second order, the QUADRUMANA, contains the monkeys and lemurs, who are provided with hands at each of the four extremities. The teeth of Quadrumana are of two kinds; the monkeys resembling man in having blunt tubercles on the molars or grinding teeth; but the lemurs having sharp tubercles, like those of the insectivorous animals of the next order.

III. The CARNIVORA form the third order, and include a large number of species, living almost exclusively on animal food. They are nearly all quadrupeds; the form of their teeth is better adapted to cut than to grind food; their jaws are nearly incapable of lateral motion; and the form of the skull is modified to give great strength and volume to the muscles which work the jaws.

They are subdivided into four great families: (1) the *Chiroptera*, or bats; (2) the *Insectivora;* (3) the true *Carnivora*, (containing two sub-families, *Plantigrada* and *Digitigrada*), distinguished by the structure of the extremities; and (4) the *Amphibia*, inhabiting the sea, whose extremities are short and rudimentary, and intended to serve rather as fins than feet.

The teeth of the Carnivora vary considerably according to the habits of the different tribes. Those of the bats, which feed for the most part on vegetables and insects, but sometimes pursue small birds and even quadrupeds, are studded with conical points, and, in this respect, resemble those of the Insectivora. The extremities of the first family are, however, modified for flight in a very remarkable way; whereas those of the other, which includes

the mole, the shrew, and the hedgehog, are sometimes so contrived as to enable the animal to live almost entirely beneath the surface of the earth.

It is only when we reach the true Carnivora that we find a sanguinary appetite for flesh, joined to great strength and activity. All the genera of this subdivision have long, stout, and separated canine teeth or tusks, between which are six incisive teeth in each jaw, and the molars are wholly cutting, as in the feline tribe, or are blended with blunted tubercles, as in the bear. Of the two sub-families, the *Digitigrade* includes (1) weasles &c., (2) the dogs and civets, and (3) the hyæna and cat tribe, animals all naturally extremely carnivorous, and walking upon the extremity of the toes and fingers. The *Plantigrades* walk upon the extended palm; they are much slower than the Digitigrades, and are able to support themselves on their hind feet in climbing trees, or in seizing their prey. The bears are the type of this tribe, and their tuberculated molar teeth indicate the frugivorous habits which, under ordinary circumstances, these animals exhibit.

Lastly, the Amphibia, including the seal and the morse, form a family of marine Carnivora, their extremities being adapted to the element in which they are to live.

IV. The Marsupials are animals of which the female, after bringing forth her young alive, receives them for a time into a peculiar pouch, to which they have recourse for shelter at the approach of danger, even long after they are able to walk.

The subdivisions of this order seem to form groups analogous to the different orders of Mammalia; their mode of dentition is extremely variable; they are, with very few exceptions, peculiar to New Holland, and their habits are ill understood.

V. Rodentia. This order includes a number of animals provided with two large incisors in each jaw, separated from the molars by a vacant space, and acting as chisels or files, enabling the animal to gnaw wood and other substances, with great facility. With this structure of the incisors there is combined a peculiar form of the molar teeth, which have flat crowns, whose enamelled eminences are so arranged as always to be in opposition to the horizontal movement of the jaw, and which serve admirably for trituration. The beaver is a good example of an animal of this order, which also includes the squirrel, the rat and mouse, the hare and rabbit, the guinea-pig and the dormouse.

VI. The Edentata are animals without teeth in the front of the jaw; and in their large nails, which embrace the extremities of the toes, as well as in the gigantic proportions of some extinct species, they seem to form a link between the unguiculate animals to which they belong, and the ungulata or hoofed quadrupeds. The anatomy of the animals of this order is extremely interesting to the Geologist, as a considerable number of extinct species, lately discovered in South America, have been referred to it, although in magnitude they far exceed the dimensions of the largest species now known to exist. The Edentata were subdivided by Cuvier into three tribes: (1) the sloths; (2) the ordinary Edentata, including the armadillo and the ant-eaters, and (3) the *Monotremata;* whose habits are so peculiar, and their structure so anomalous, that its two genera are with difficulty included in any general definition.

The molars in all the Edentata are cylindrical or subcylindrical, having an outer coating of enamel, harder than the substance of the tooth, and, with the exception of the sloth, which lives suspended from the lower side of the

branches of trees, almost all the existing species dig and burrow in the earth.

The "Ungulata" of Linnæus, were grouped by Cuvier into the two orders, *Pachydermata* and *Ruminantia;* the latter of which contains all those hoofed quadrupeds who return their food to the mouth to be masticated, after having first deposited it in a false stomach;—this process being called ruminating.

VII. The Pachydermata, or thick skinned animals, are sufficiently remarkable not to require any long description. They are subdivided into (1) The *Proboscidiana*, or those provided with a long trunk, as the elephant; (2) the ordinary Pachyderms, viz. the hippopotamus, the pig, the rhinoceros, the tapir, and several extinct genera; and (3) the *Solipedes*, of which the horse is the type.

VIII. The Ruminants form an order containing by far the greater number of the animals useful to man, but whose remains are exceedingly rare in a fossil state, except in strata of the most recent period. It is sufficient to mention the names of the different genera of which this order is made up, to recall their peculiar habits and structure. The camel, the deer tribe and antelopes, the giraffe, the goat, the sheep, and the cow, are all perfectly well known. They are all characterised by the peculiar structure of the stomach, already alluded to, and by the absence of incisors, or cutting teeth, except in the lower jaw, where they are eight in number: there is also a vacant space between the incisors and molars, which latter have their crown marked with two double crescents, the convexity of which is turned inwards in the upper, and outward in the lower jaws.

IX. The last order of Mammalia is that of Cetacea, under which name is included a number of warm blooded

animals, much more resembling fishes than quadrupeds, both in their external appearance and habits. In every case, however, anatomical investigation has shown that there exist, in a rudimentary state, all the bones which mark the approximation, in structure, of these animals (apparently fishes,) to the most highly organized vertebrata.

The ordinary whales are more or less carnivorous in their habits, but some of the largest of them, although of gigantic size, are entirely without teeth, and live on the small worms, mollusca, and zoophytes, which float by myriads in the seas; and this food they separate from the water by a net-work of elastic bone in the upper jaw,—the water being violently expelled, from time to time, by a narrow opening on the top of the head. The herbivorous whales are distinguished by their flat-crowned teeth, indicating their mode of obtaining food, and they are not provided with the blowing apparatus above alluded to.

Of the other vertebrated animals, the Birds were defined by Cuvier to be "Oviparous Vertebrata, with double systems of circulation and respiration, organized for flight." In these animals the circulation is much more rapid, and the respiratory organs more complete and active, than in Mammalia; and there are particular contrivances for this purpose, not only in the structure of their lungs, but also in their bones and integuments. Their remains are, however, so very rarely found in a fossil state, that it will not be necessary to dwell on the details of their classification.

Reptiles are cold-blooded animals, by which is meant that only a portion of the blood passes from the heart to the lungs at each respiration. They are oviparous, but do not, like birds, hatch their eggs by sitting upon them.

Their brain is small in proportion to the size of the body; their habits for the most part are slothful; their digestion is tedious; their sensations blunt; they are capable of enduring extreme cold and hunger without exhibiting apparent pain; and they can also exist for a long time in a state of torpidity.

FISHES are also cold-blooded and oviparous, and they breathe by gills instead of lungs, and through the medium of water,—to which element alone their organization adapts them. They are inferior in all points of structure to the other vertebrata, and form a link uniting the most highly organized beings with those more simply constructed; from which we are led, by insensible gradations, to the lowest and least complicated. There are some cases in which the fish, possessed as it is with a rudimentary brain and the appearance of a vertebral column, falls short, in completeness of organization, of some of the higher Invertebrated Mollusca.*

The INVERTEBRATA are conveniently described under four classes, of each of which I proceed to give a short notice. The most characteristic points in their structure relate to the nervous system; and, as a group, they are described as having several centres of nervous matter, not arranged in pairs, but variously distributed in different parts of the body. One large mass occupies a position above the æsophagus and stomach, and communicates with the nerves of the external senses; thus serving as the substitute for a brain.

The first class of invertebrated animals, and that which exhibits the most complicated forms of organization, is called

* An account of the subdivisions, both of the fishes and reptiles, I postpone till a future chapter, when such account will form a fit introduction to the descriptions of the extinct species referred to those classes.

MOLLUSCA, and is subdivided into seven orders. Of these the *Cephalopoda* exhibit the nearest approach to vertebrated animals: they usually possess an internal osseous skeleton, but are occasionally provided with an external shell, secreted by a fleshy skin called the mantle. The animals of this order are common in a fossil state, and will be described more at length in speaking of the extinct species found in the older rocks.

The *Pteropoda*, the next order of Mollusca, comprises only a few species; but these are incredibly abundant; and the individuals referred to them swim in myriads through the ocean, forming occasionally the food of the largest living animals. The Pteropoda are provided with broad fleshy expansions, or fins, which enable them to move rapidly through the water, and distinguish them from the *Gasteropoda*, to which they are in other respects nearly allied.

The *Gasteropoda* are so called from their peculiar method of locomotion, the animal gliding slowly along by means of contractions of the fleshy skin with which it is covered. This order includes the whole tribe of land and water univalve shells, with the exception only of the Cephalopoda.

The fourth order of Mollusca, the *Conchifera*, also includes a very extensive and well known group of animals, comprising, with few exceptions, the inhabitants of all bivalve shells. These exceptions are formed into a fifth order, the *Brachiopoda*, which is so named from two long spiral arms placed on either side of the mouth of the animal, and, in some species at least, capable of being unrolled to a considerable length and protruded in search of food. This singular contrivance being accompanied by the existence of a peculiar respiratory apparatus, and

other remarkable differences of structure, justifies the establishment of a distinct order.

A group of very singular animals, enveloped in a tough skin, but often so delicate as to be perfectly transparent, forms a sixth order, under the name *Tunicata*; while the last or seventh order, the *Cirrhopoda*, so strangely combines the limbs of the Articulata with the external characters of the Mollusca, that it may almost be looked on as intermediate between the two. The Cirrhopoda receive their name from certain hair-like appendages, by whose rapid motion a species of current is formed in the water, attracting in its vortex any light small animals that may be floating about within reach of the mouth, by which they are at once seized and crushed.

The class ARTICULATA includes five orders, sufficiently well known as to require merely the mention of their names. They are the *Crustaceans*, (crabs, lobsters, &c.); the *Arachnidans*, or spiders ; the *Insecta*, or true insects; the *Myriapoda*, or centipedes; and the *Annelidans*, or worms.

The RADIATA of Cuvier have been separated by later naturalists into two groups; of which one, exhibiting the higher types of organization, and having a distinct nervous system, is called NEMATONEURA (*νημα*, a thread), from the thread-like form to which that part of the animal structure has become reduced. It is divided into five orders, of which the first is the *Echinodermata*, and includes a vast number of fossil species. The animals of this order are for the most part highly typical of that peculiar radiated structure which has given its name to the class, and the body usually consists of five similar parts, symmetrically disposed. This curious structure is carried out to a remarkable extent, and may be traced from the glo-

bular shell of the sea urchin to the infinitely branching crinoidean, found in a fossil state, and whose organization can have advanced but little beyond that of the most simple polyp.

The remaining orders of Nematoneura are, (2) the *Epizoa*, or external parasitic animals ; (3) the *Rotifera*, or wheel animalcules ; (4) the *Bryozoa* ; and (5) the *Cœlelmintha*, or internal parasitic animals which are, for the most part, found preying on the integuments of other animals, and are so minute as usually to require the aid of the microscope in order to observe them.

The second group of Radiata exhibits the lowest and most simple forms of animal life, and has been called Acrita. It includes five orders ; but none of the species referred to it show any trace of nervous structure, most of them having scarcely any of those functions which we are in the habit of considering inseparable from vitality. The first order is called *Sterelmintha*, the different species of which live exclusively in the alimentary canal, the liver, the brain, and other parts of more highly organized animals ; (2) the *Acalephæ*, animals floating in swarms in the ocean, and exhibiting to the common observer the appearance of a lump of jelly, and no traces of that elaborate structure which they really possess ; (3) the *Polygastrica*, or infusorial animalcules, of which myriads may be found in every pool of dirty water, and which increase so rapidly, that from a single animal as many as 270,000,000 of new beings may be produced in a month ; (4) the *Polyps*, including the coral animalcules, whose labours in secreting and depositing carbonate of lime are permanently recorded in the history of the world, and which have, by their vast numbers, and never ceasing activity, actually formed a large proportion of the solid materials of the earth ; and,

lastly the *Sponges*, those animals, if indeed, they can be called animals, which give no indication of any sensation, which have no voluntary motion, which exhibit no internal receptacle for food, no apparatus for digestion, and in fact, which only differ from the solid rock to which they are affixed by the possession of canals, which communicate with one another, and permeate the whole body, conveying the water which surrounds the mass to all parts of its structure.

THE DODO.

CHAPTER IV.

EXTINCT SPECIES OF ANIMALS. — LAW OF MUTUAL RELATION OF STRUCTURE TO HABITS. — DISTRIBUTION OF EXTINCT SPECIES. — GENERAL RESULT OF PALÆONTOLOGICAL INVESTIGATIONS.

Having now given an outline of the nature of the classification of animals as established by Cuvier on general views of structure, I proceed to apply the subject to Geology, and to show how by the aid of Comparative Anatomy the Palæontologist is enabled to refer a fragment of an organized body presented to his notice to some known species, or to explain and define its analogies with existing forms of structure, although it belongs to a species which has passed away.

Nor need it excite our astonishment that species as well as individuals should cease to exist, and new ones be introduced in their stead. Apparently without the agency of man, and not merely because where he appears some animals are driven away and others encouraged, there are many instances on record of species which once were sufficiently abundant, being now very rare, or altogether lost; and there can hardly be a doubt that one species, at least, the *Dodo*, has entirely disappeared as a living animal only within a very recent period. The *Apteryx* of New Zealand is another animal that appears to be gradually becoming extinct; and many species, such as the wolf, the beaver, and the bustard, are already locally extinct in our own country, and must ultimately become so throughout Europe.

And, moreover, if we examine the gravel, of which such vast quantities are spread over the surface of the earth in northern Europe, we find many bones of large animals distributed through it, not belonging to the species now living in the neighbouring districts: and, when we endeavour to trace this gravel to its source, we find it necessary to go northwards, and even, in some cases, to approach those vast fields of ice which extend round the North Pole of the earth. On reaching these desolate regions, where now the polar bear and the seal reign undisturbed, and the only vegetation that exists consists of red patches of lichen, discolouring the snow, we learn that, for centuries past, they have been annually visited, for the purpose of obtaining, from the cliffs of frozen gravel which bound the shores of the polar seas, the bones and teeth of elephants and other large herbivorous quadrupeds. These remains, also, are so abundant that whole cargoes are readily obtained, and they even formed, for a long time, a principal source of the supply of ivory in northern Europe. The remains thus found are not mere broken fragments which have been washed by marine currents to these desolate regions, but are in perfectly good condition; and, at the close of the last century, an individual elephant was laid bare in a perfect state, the flesh and skin covering the bones, and the skin being clothed with a considerable quantity of wool and hair.

If, however, among the remains of large animals found in the different strata of which the earth is composed, there are some, as those of elephants, certainly not now existing in a living state in the same latitudes, there are also many others which, not being known, we may fairly conclude do not now exist at all; because it is in the highest degree improbable that there are any large ani-

mals on the earth yet to be discovered. As, therefore, if such remains should be found not to represent any known living species, this cannot be the effect of chance; so, neither can it be that all the species to which the fossil bones must be referred are hidden in the distant corners of the earth, and have hitherto escaped the searching eye of the traveller.

The consideration of the fossil remains of the Vertebrata, while it is undoubtedly the subject of highest interest to the Palæontologist, is also surrounded by numerous and peculiar difficulties, and these are heightened and increased when the most highly organized of all,—the Mammalia, are considered; and when it is the object to make out from a few bones presented for examination all the peculiarities and habits of a species hitherto totally undescribed and unknown. But it is precisely for this reason that the determination of new species of quadrupeds is the most valuable and the most interesting of all the results attained by the comparative anatomist, and that which exhibits most clearly the nature of the argument, and the importance of the analogies, by the proper application of which similar conclusions are more readily drawn in simpler cases. Fossil shells are generally found perfect, and may be immediately compared with recent species in the collection of the conchologist, and even the remains of fish usually exhibit the skeleton more or less complete, the form of the body, and other generic and specific characters being preserved; but, in the case of quadrupeds, it is rarely more than a few isolated fragments heaped confusedly together, and often broken and injured, that are presented to the naturalist as the foundation of his descriptions.

"For this reason," Cuvier remarks, "most observers have passed over the subject in a cursory and superficial

way, rarely venturing to give a name, or assign a place, to such fossil remains; and thus has the study of them,—the subject most important of all, been also the most neglected."*

It is fortunate, however, that there does exist a principle, deduced from an accurate knowledge of Comparative Anatomy, which, properly developed, is capable of banishing all doubt and obscurity: it is *that law of the mutual relation of general and special structure in organized beings, by means of which each species may be identified by even a fragment of any one of them.* Let us consider, shortly, the nature of such mutual relation of different parts, in illustration of the law thus propounded.

Every organized being may be considered as an entire and perfect system, of which all the different parts mutually correspond and concur in the same definitive action by a reciprocal re-action. No one part can undergo a change without a corresponding change taking place in all the others; and, consequently, each part taken separately indicates and gives the key to a knowledge of all the rest.

Thus, if the stomach of an animal is so organized as only to digest fresh animal food, its jaws must also be so contrived as to devour such prey; its claws to seize and tear it; its teeth to cut and divide it; the whole structure of its locomotive organs to pursue and obtain it; its organs of sense to perceive it from afar; and nature must even have placed in its brain the necessary instinct to enable it to conceal itself and to bring its victim within its toils. Such will be the general conditions of a carnivorous animal;

* I have here, and throughout the rest of this chapter, endeavoured to make use, as much as possible, of the words of Cuvier in explaining the nature of his argument, although I have not referred to the particular pages at which the remarks I have borrowed will be found.

they must inevitably be brought together in every species intended to be carnivorous, for its race could not subsist without them; but under these general conditions there exist also special ones, relating to the size, the habits, and the haunts of the prey on which the animal is to exist; and from each one of these special conditions there result certain modifications in detail of the form required by the general conditions; so that not merely the class, but the order, the genus, and even the species, will be found expressed by, and deducible from, the structure of each part,

In order, for example, that the jaw may be enabled to seize the prey, there must be a certain shaped prominence for its articulation, a certain relation between the position of the resistance and that of the power, with respect to that of the fulcrum, a certain magnitude of the muscle that works the jaw, requiring corresponding dimensions of the pit in which that muscle is received and of the convexity of the arch of bone beneath which it passes, while this arch must also possess a certain amount of strength to enable it to bear the strain of another muscle.

That the animal may be able to carry off its prey a certain degree of strength is necessary in the muscles which support the head; whence results a peculiar structure in the vertebræ to which these muscles are attached, and in the back of the skull where they are inserted.

That the teeth may be adapted to tear flesh they must be sharp, and they must be more or less so, exactly according as they are likely to have more or less flesh to tear, while their bases must be strong in proportion to the quantity of bone and the magnitude of the bones they have to break. Every one of these circumstances also will have its effect on the developement of all the parts which assist in moving the jaw.

That the claws may be able to seize the prey, there must be a certain amount of flexibility in the toes, and of strength in the nails; and this requires a peculiar form of the bones, and a corresponding distribution of the muscles and tendons; the fore-arm must possess a certain facility in turning, whence also result certain forms of the bones of which it is made up, and these bones of the fore-arm, articulating to the humerus, cannot undergo change without corresponding changes taking place in this latter bone. The bones of the shoulder also require to have a certain degree of strength when the anterior extremities are to be used in seizing prey; and in this way again other special forms become involved. The proper and free play of all these parts requires certain proportions in all the muscles concerned in the motion of the fore-leg, and the impression of the muscles so proportioned will determine still more definitely the structure of the bones.

It is easy to perceive that similar conclusions might be drawn as to the structure of the posterior extremities, which contribute to the rapidity of the general movement of the body; or of the vertebræ, which influence the facility and flexibility of those movements, and also as to the structure of the bones of the face in their relation to the degree of developement of the external senses. In a word, the structure of a tooth involves that of the socket in the shoulder bone, and of the nails, just as—to use a mathematical but very apt illustration—the equation to a curve involves all the properties of the curve; and, as the curve may be drawn when we know one root of the equation, so, in Comparative Anatomy, by making each property separately the base of investigations, one may deduce all the other properties. Thus the shoulder bone, the articulation of the jaw, the thigh bone, or any other bone taken separately,

gives the structure of the tooth, or, conversely, from the tooth, a knowledge of these peculiarities may be derived; so that, taking any one bone, he who is familiarly acquainted with the laws of the animal economy may reproduce the whole animal.

But this principle of analogy, which may seem to be sufficiently evident, and not to require further demonstration, may often be carried out to a still greater extent, and applied in cases where theoretical knowledge of the mutual relations of structure would not be sufficient, unless supported by, and even founded on, actual observation.

As an instance of this we may refer to the hoofed animals, of which it is easy to predicate that they must be herbivorous in their habits, because they have no means of seizing prey, their feet being only adapted to support the weight of the body, and their flat-crowned teeth, and the horizontal motion of the jaw, to bruise and triturate seeds and grass. But although up to this point the relation of structure to habit might be suggested by the general argument of analogy, there are other relations of structure, the reason of which appears less palpable in proceeding to the consideration of the different orders of Ungulata. It is not difficult to perceive, that, on the whole, the digestive apparatus must be more complicated as the dental apparatus is less perfect; and thus we might expect that such and such animals wanting a certain kind of teeth would, rather than others, be Ruminants; and one may also connect a certain form of œsophagus with corresponding structure of the vertebræ of the neck. But it could hardly be imagined, without actual observation, that the Ruminants, and they alone, should have cloven feet; that in this class only should occur animals possessing true horns on the forehead, and that such of the species as are

provided with sharp canine teeth, should for the most part be without such horns.

These relations, however, being found to exist, and resting on a sufficient number of facts, the laws which govern them, although deduced by observation, and not by *à priori* reasoning, are as much to be depended on as any others. Thus, for instance, any one at the present day merely seeing the track of a cleft foot, might safely conclude that it had been left by a ruminating quadruped; and this footmark alone is sufficient to give to the observer a knowledge of the structure of the teeth, the jaws, the vertebræ, the bones of the extremities, and the pelvis of the animal that had passed; but, whatever may be the laws of this relation of the parts, we owe a knowledge of their existence to observation and not to abstract reasoning.

When, however, the facts are brought together upon which our knowledge of such empirical laws is grounded, it will be found that not only is there a consistency so far as species is concerned between a certain structure of one organ and a corresponding structure of another; but the same consistency obtains, and a corresponding analogy of a higher order exists, in those more comprehensive groups which are called families, and even orders; and in the continued trace of such analogies throughout various generalizations, we see their importance and the mutual influence of the parts compared, almost as clearly as if we knew the actual cause.

Referring, for instance, once more to the ruminating Ungulata, let us compare them with the others of the same subdivision who do not ruminate. We shall find that the dental system of these latter is usually more perfect than that of the former, inasmuch as they have either incisive

or canine teeth and usually both, in *each* jaw; and we shall also find that the foot is generally more complicated, provided either with a greater number of toes; or with nails which less completely envelope the bones of the extremity of the foot; or with the bones of the leg more distinct from one another; or, lastly, that several, or all of these combined, exhibit a still greater degree of complication of structure than any one separately. Now, although the cause of this is not known, it is clearly no effect of chance; because whenever the structure of one of the cleft-footed Ungulata exhibits in the character of the teeth any tendency to approximate to the Pachyderms, it invariably exhibits a corresponding tendency in the structure of the foot. Thus the camels, which are provided with canine and even incisive teeth in the upper jaw, and in this point differ from other Ruminants, differ also in having extra bones of the foot and very small nails. The musks, again, whose canine teeth are much developed, have the two bones of the hind leg (the tibia and fibula) distinct along their whole length, while the other Ruminants have these bones fastened together, and the fibula usually very small. It appears then, that there is a constant harmony and analogy of structure between two organs, having, in appearance, very little to do with each other; and the gradations of structure correspond regularly, even in those cases in which we are not at all able to discover the cause.

When we adopt the conclusions thus obtained from observation and comparison, in addition to those before arrived at by reasoning, we are led to results not a little astonishing; for it then appears, that the smallest surface of bone may possess a meaning, and have reference, not only to the class, but the order, the genus, and even the species, to which the animal belongs. This is, indeed, so much the

case, that it is possible for the comparative anatomist, with attention, and making use of the aids of analogy and actual comparison, to determine a species and its relations with other allied species from any well-preserved extremity of bone; and Cuvier mentions, that in the course of his experiments, he has frequently proved this on fragments of animals already determined, before so completely putting confidence in his knowledge as to decide on fossils, but that it had always been followed by complete success, and that he could no longer doubt the certainty of the results thus obtained.

Such, then, is the method and the principle, by the proper application of which the Palæontologist may obtain a knowledge of the analogies and the peculiarities of structure, and even some idea of the habits of animals of which only a few fragments remain; and in this way Cuvier himself, from remains found chiefly in the neighbourhood of Paris, determined no less than ninety species, not one of which is now represented on the earth by any living creature. Of the multitude of fragments which came under his observation, he was enabled by these means to refer them all, one after another, each to its proper species, when it belonged to a known species, to its genus when its species was unknown, and to its order when referable to a new genus; assigning, in all cases, the proper characters which distinguished the new discovery from the genera and species most nearly allied. "No more than this," he observes, "has been attempted by Naturalists when the entire animal was before them."

I have thus, although very briefly, both illustrated and explained that remarkable law of "the mutual relation of general and special structure in organized beings, by means of which each species may be identified by even a fragment

of any one of them;" and so far I have fulfilled my object, as stated in the commencement of this chapter. But, before proceeding to describe in detail the different strata, and the animals, or groups of animals, characteristic of each of them, it may perhaps be worth while to give a general view of the distribution of fossils throughout the various formations.

The remains of Mammalia are, with one solitary exception, confined to those strata which, as they are deposited upon all the others, are, with reason, supposed to have been the most recently formed. But even in these "*Tertiary formations*," as they are called, such remains are much more abundant in the upper, than in the lower strata.

Of Mammalia, the remains of MAN have never yet been discovered in a fossil state, except in a limestone very rapidly forming in the island of Guadaloupe, and under circumstances which leave no doubt of the recent origin of the deposit.

There have been found, in one or two instances, the teeth of extinct species of *Monkeys;* but these are extremely rare; and so are also the remains of *Bats*, and of the Insectivorous Carnivora. The true Carnivora are more abundant in a fossil state; and their remains are found, both in gravel and also in numerous caverns in limestone rocks, which appear formerly to have served these animals as dens. The total number of extinct species is, however, very small.

The only Mammals whose remains occur in rocks older than the Tertiary period are referred to the order *Marsupialia;* two extinct genera of these have been described from the secondary rocks of England, and others are known to occur in tertiary strata in New Holland.

Jaws, teeth, and fragments of bones of *Rodentia* are occasionally found in the upper tertiary strata, and are sometimes associated with the cavern bones.

In the various orders hitherto glanced at, the number of extinct species hardly bears any proportion to that of the existing species; but, in the *Edentata* and *Pachydermata*, the contrary would seem to be the case; and the remains of these animals are very abundant in particular localities, offering many remarkable peculiarities of organization. Of the existing Edentata, the largest species does not attain a magnitude of more than four feet in length; whereas, in the beds of gravel which form the plains of South America, near the river Plata, the bones, and even the complete skeleton, of animals of this kind have been discovered, indicating a species not less than eighteen feet in length. Of the Pachyderms, again, only twenty-one species were known at the time of the publication of the "Regné Animal;" but more than twice that number of extinct species have since then been added to the list. These extinct Pachyderms are of very great interest, both to the palæontologist and to the zoologist, as they are in many places so intermediate in character between known species as to supply links in the chain of species, the absence of which was extremely perplexing.

Of *Ruminants* but few extinct species are known; and these few are principally remarkable as exhibiting analogies with the Pachyderms. A few *Cetacean* remains have also been found, in the upper tertiary formations, both in England and America.

The remains of *Birds* are so rare and so imperfect in a fossil state that little can be said of them, except that they appear to be referrible to aquatic species, and probably to the order *Grallæ*. Footsteps of a large size,

which resemble those that would be left by the trampling of birds over mud, have been observed, in one locality in America, in a stratum of great antiquity.

The extraordinary abundance of the remains of *Reptiles*, in strata very low down in the series, is one of the most striking and remarkable of those discoveries which are the result of geological investigation. Most of the species thus made known are totally unlike, both in structure and habits, any existing reptiles; and they present anomalies, and also analogies of extreme interest. Not less than twenty-three new genera and subgenera have been added to the list of reptiles, determined from the fossil remains of animals of this class found in England alone; and Zoology has in this way received most valuable additions.

It might have been expected that, as most of the strata with which we are acquainted were deposited from water, the remains of fish and other aquatic animals, either marine or freshwater, should be more abundant than those of the inhabitants of the land; and this is indeed most remarkably the case; for the number of extinct species of fish that have been determined amounts to many hundreds, and far exceeds that of all the other extinct Vertebrata; while extinct species of invertebrated animals, chiefly Mollusca, are extremely numerous in every formation; each separate stratum being characterised by some species or group peculiar to it, or very abundant in it. It is chiefly by means of the fossil remains of Invertebrata that strata are identified; and a knowledge of the most remarkable and characteristic fossils of this kind is, therefore, extremely necessary, and will also be found to possess great interest.

In this rapid sketch of the zoology of the various

formations, I have not dwelt upon any details of structure, or even peculiarities of form, of the extinct animals; nor have I yet said one word of the vegetable remains also found most abundantly in some of the older groups of strata. Without, however, anticipating any remarks I may hereafter have to offer, I may safely conclude these introductory chapters by assuring the reader that, with regard to the various discoveries of Palæontology, they all speak the same language, and all support the same argument; namely, that, in the order of succession of those species of animals or vegetables which have preceded man upon the earth, as well as in the composition of the various strata in which they are found entombed, there may be traced, throughout, an unity of principle, acting by an infinite variety of means: and one system, perfectly symmetrical and beautiful, and adapted to every emergency, has been invariably pursued from the first creation of organized beings till now. From that far distant period when the inhabitants of the earth consisted only of the coral animalcule and the mollusc, throughout the gradual introduction of animals of higher organization, until the day when man was created, and endowed with an intellect capable of comprehending and appreciating the infinite wisdom displayed in the great plan of creation, that plan has been the same; gradually unfolding itself until fully developed in all its extent and perfection.

PART THE SECOND.

DESCRIPTIVE GEOLOGY.

I. THE DESCRIPTIVE GEOLOGY OF FOSSILIFEROUS STRATIFIED ROCKS.

CHAPTER I.

PLAN OF ARRANGEMENT, AND REASONS FOR SELECTING IT.—THE NATURE OF GEOLOGICAL CLASSIFICATION.

I HAVE already observed, in defining the meaning of Geology, that its ultimate object is to give an account of the original formation of the crust of the earth, and of the nature and causes of the successive changes that have taken place both in the physical features of the globe itself, and also in the inhabitants which have from time to time dwelt upon it. The history of such changes is that part of the subject which I now proceed to narrate, under the title of "Descriptive Geology," and the object of this preliminary chapter is, to explain the order and method that will be adopted, and the nature of the different subdivisions under which the subject will be considered.

It has, hitherto, been most usual in elementary works on Geology, to introduce the student to a knowledge of the older formations by first describing the others of more recent date, and in this way preparing him, as it were, for those striking differences which the former present both in mineral structure and fossil contents. This method is not without many advantages, and was especially adapted to

that condition of the science, when little was known with certainty of the order of superposition and the palæontology of the older rocks.

Since, however, within the last few years great and successful efforts have been made to remove the veil of obscurity, which, for a long time, hung over almost all departments of the geology of the most ancient formations; and since, on the other hand, there are still so many difficulties to be overcome in making the first step from the present to the past, it now seems to be the easiest and the most satisfactory method, to quit at once (except for purposes of comparison,) the consideration of present appearances and effects now produced by existing causes, and contemplate a condition of things, at first widely different from existing nature, but by gradual and successive steps approximating and becoming more and more analogous to it.

Following, then, as far as possible, the succession exhibited in nature, I mean to introduce the facts of Geology in the order of their occurrence, and in relating the successive changes by which the crust of the earth has been brought to its present condition, I shall begin with a description of those strata which appear to have been the earliest formed, and whose vast extent, and numerous groups of interesting fossils, have only lately been recognised in Geology. In this way the reader will be gradually prepared for the phenomena of the secondary and tertiary strata, which being to a certain extent derived from, and consequent upon, the older rocks, can only be properly understood when considered with reference to them.

But there is an additional reason why, at the present time, and in the actual state of geological knowledge, the method I adopt is the most likely to be useful. A large

proportion of the actual surface of the earth having been visited by intelligent and observant travellers, and the geological structure of extensive tracts in distant countries having been compared, it has been found, that while the newer formations are for the most part very confined in their range, and their fossils, although of the same geological period with others found in similar deposits in other districts, rather referrible to species analogous to than identical with them; in the older rocks, on the other hand, many species found at distant parts of contemporaneous formations are identically the same; and there is, on the whole, less dependance to be placed on those which appear to be characteristic of a particular bed. In the lowest formations, indeed, which in our own country exhibit a thickness of many thousand feet of strata fossiliferous throughout, there appear to be few distinct and well-marked differences of a palæontological nature, which enable us to assign a particular part of the series for particular species; although, as we proceed to the investigation of the upper strata, such characteristic fossils unquestionably exist; and that, too, in beds not a hundredth part of the thickness of these lower ones, and which we may fairly conclude were deposited in a much shorter time.

The strata occupying the lowest place in the geological sequence, have also been observed to pass, in almost every instance, by gradual and imperceptible changes into non-fossiliferous rocks; and, for this reason, in addition to others which will hereafter appear, it has been thought probable, either that these lowest strata were, in reality, the beds first deposited upon the earth, and that the animals whose remains are found in them were its first inhabitants; or, at least, that no fossiliferous rocks of an older date, if such exist, exhibit any important zoological changes, or contain

species different from those with which we are already acquainted. This conclusion having been arrived at, the time has come when we may place in order the results of geological and palæontological investigations, and describe from the beginning the Zoology and Botany of the earth, while communicating the elementary facts of Geology.

Since it is thus my intention to enter at once upon the consideration of that part of Descriptive Geology which has hitherto been looked upon as the most difficult and obscure, it becomes necessary to give an account of the nature of the subdivisions that will be adopted; and, as a preliminary notice, I may mention that the various rocks of igneous origin, being usually connected with disturbances which they have produced in strata previously deposited, will be considered as forming a separate class, not to be described till after those which are known to be stratified. I, therefore, postpone for the present any detailed account of unstratified formations; and, without defining very strictly the characters which separate aqueous rocks altered by heat from true igneous rocks,—a distinction often difficult to be drawn, and sometimes impossible, — I only include, in this first division, those in which the existence of fossils has been proved; because they alone appear to furnish any certain evidence in doubtful cases.*

The whole series of fossiliferous stratified rocks may be conveniently divided into three great classes, or principal groups of formations, respectively denominated Palæozoic, Secondary, and Tertiary: these three being sufficiently well marked and distinctive, at least in Europe, to be generally received in Geology.

* See p. 94, and also the chapters on altered rocks in the commencement of the second volume.

In order, however, to understand the value, and even the meaning, of these and other subdivisions in Geology, they require to be considered with reference to the actual origin of stratified rocks: and, for this purpose, reverting to a method already adopted in explaining technical terms and phrases, let us assume, for the moment, that the whole series of strata which we find in England were deposited successively from water, but that, during this long period many great alterations of level had taken place; the beds being occasionally depressed,—admitting of the deposit of new strata upon them,—and occasionally elevated, and becoming dry land. During the whole period, let us also assume a like gradual and successive change, affecting organized beings both of land and sea. It must be clear that, in such a condition of things, there would be three different states in which the actual solid surface, whether above or under water, might exist: it might be the bottom of the sea, and the recipient of deposits then going on; or it might be also under water, but far removed from the neighbourhood of land, and receiving no additions corresponding to those made under the first supposition; or, lastly, it might form an island or continent, and be exposed to constant denudation, losing a part of what it had formerly received. At another period, the circumstances might be altered; but that portion of solid surface which had existed for a long time without the deposition of new beds, as well as that from which the uppermost surface had been denuded, would necessarily exhibit, in the remains of organized beings found in it, an amount of change corresponding to the period during which there was no additional deposit.

Now, if we consider how large a proportion of the earth there must be at present receiving no new deposits

of any kind, and the probability that such a condition must always have existed, and then turn to the contemplation of geological phenomena, we shall cease to wonder at the occasional appearance of breaks in the successive groups; and we shall rather be astonished at the slow and stately progress of the changes that have taken place, and the vastness of the machinery set in motion to produce the effects actually observed in stratified rocks.

The nature of geological classification, then, is thus explained: Depositions constantly going on, at one point or another, and elevatory movements or depressions of the surface having been equally incessant, there have been, from time to time, such changes produced, either suddenly or gradually, that, in a particular spot, a pause has occurred, and a break in the deposition of strata; so that, when the deposit again commenced, a change had taken place in the nature of the inhabitants of that spot, sufficiently marked to exhibit a distinct character when the fossil remains are carefully examined and compared. From time to time, these pauses have been longer; and larger tracts have been withdrawn from the influence of aqueous deposition for a longer period; so that we are able also to group together several strata, each stratum being itself more or less distinguishable from the rest. Lastly, there are still more remarkable breaks, distinguished yet more decisively; and these form the fundamental divisions into which all the rest arrange themselves, and to some one of which every stratum may be referred.

Viewing Geology in its greatest generality, there is perhaps but one of these latter decided and well-marked lines to be traced throughout the whole series of formations. It is that which separates the strata above the Chalk from all that are subjacent: and even this separation

cannot be looked upon as a universal phenomenon, although it is so extensive that no instance of any real transition of the one series into the other has yet been discovered in Europe, Asia, or America.

Although, however, there is no very clear line of demarcation to be drawn between the different and numerous groups of the rocks of older date, there yet does appear to be one sufficiently remarkable in the change which takes place in the general character of the fossil remains at certain points; and this is a distinction observable throughout Northern Europe, and, probably, also in America.

Taking advantage of this, the whole series of formations, from the chalk downwards, has been separated into two parts; to the lower of which the name of PALÆOZOIC has recently been applied; the upper beds being called SECONDARY; while the beds above the chalk are distinguished by the term TERTIARY.

In the early history of Geology, formations, of whatever period, were called primary or secondary, according as they appeared to be non-fossiliferous, or to contain organic remains. At that time, however, none but the newest members of the series now called Palæozoic were recognized as fossiliferous; and, as the rest were gradually brought into notice, they received the names, *transition*, *primary fossiliferous*, *grauwacké*, &c.; names derived from local peculiarities, and involving theories most of which are now given up.

The name *Palæozoic*, indicating merely the fact that the strata so called contain the fossil remains of the earliest formed animals, may, with great advantage, be employed to designate a comprehensive group; and, from its perfect applicability, and the absence of any allusion to theory, it is likely soon to come into general use.

The further subdivisions of the fossiliferous rocks will be best understood by referring to the following table, in which each formation, or group of strata, is placed in the order in which it is found in nature, the lowest being the first named; and the groups of formations are collected together into systems, and, lastly, these systems into the three divisions which have been just explained:*

I. PALÆOZOIC.†	The Sub-Silurian and Lower Silurian Formations. (*Protozoic* of Prof. Sedgwick.) The Upper Silurian Group. The Devonian System and the Old Red Sandstone. The Carboniferous System, the Lower New Red Sandstone, and the Magnesian Limestone.
II. SECONDARY.	The Upper New Red Sandstone of England, and the Triassic System of Germany, &c. The Liassic Group. The Oolitic System. The Wealden Formation. The Cretaceous System.
III. TERTIARY.	The Lower Tertiaries or Eocene Group. The Middle Tertiaries or Miocene Group. The Newer Tertiaries or Pliocene Group. The Superficial Deposits of Gravel, &c., or Pleistocene Group.

* A still more complete notion of the subdivisions will be obtained by referring to the detailed table of formations given in the index.

† Proceedings of Geological Society, vol. iv. p. 223. See also a map, arranged by Mr. Murchison, and recently published under the superintendance of the Society for the Promotion of Useful Knowledge.

THE OLDER PALÆOZOIC PERIOD.

CHAPTER II.

ORDER OF ARRANGEMENT OF THE OLDER FORMATIONS.—CUMBRIAN AND CAMBRIAN SERIES.

It is perhaps an unfortunate circumstance for Geology that, in whatever way the subject is first viewed, it is surrounded with difficulties, arising from the impossibility of actually connecting geological phenomena with the operations now going on around us. If, for instance, we endeavour to trace back the history of the world, and pass from the consideration of the alluvial matter carried down by rivers, to that of the gravel, which appears to be the newest deposit, and one abundantly spread over various formations, we are at once struck by the utter inadequacy of any cause now in action to produce such effects. If, on the other hand, we attempt to look back to that far distant period when the world was only first beginning to assume its present form, it requires no slight effort to dispossess the mind of a certain incredulity, naturally arising from those feelings of astonishment produced by the contemplation of phenomena so unfamiliar to us, and apparently so inexplicable; and a great effort is required fully to comprehend them.

Before, however, entering on the consideration of the palæozoic rocks, this effort must be made; for in them we have a series of strata whose total thickness amounts

to many thousand feet, which contain, in rich abundance, several distinct groups of animal and vegetable remains, not one of them the same, and but few of them similar to the animals and vegetables of our own time; and these deposits are spread over a large proportion of the actual land upon the earth: the species found in them, in England, being again met with in Russia, in North America, and apparently in Australia.

To determine the order and the arrangement of these older formations was one of the most difficult works, and has been one of the most recent triumphs of Geology; for, within a very few years, the newest member of the series,—the mountain limestone formation,—was the only one which had been at all carefully investigated; and, so lately as the year 1839, the true position of an extensive group of fossiliferous rocks in Devonshire and Cornwall was still under discussion, and was then, for the first time, recognised as being a member, and not, by any means, one of the older members, of the Palæozoic division.

The oldest stratified rocks in the British Isles rest on crystalline slates, and rocks probably altered by igneous contact, (thence called *metamorphic*,) in North Wales and Cumberland; and these metamorphic rocks are also exhibited in various parts of Ireland and Scotland. They form extensive groups of strata, in which argillaceous beds and sandstones abound; while calcareous rocks are rare, and only appear as imperfectly developed limestones, generally unfit for use, either as a building stone or for lime. Throughout the series, the magnificent scale of development of the successive groups, and their wide geographical distribution, form their most striking geological feature; for there seem to be beds of the same kind,

even in distant continents, forming a common base, and possessed of great unity of character.

With regard to the lower groups of Palæozoic rocks in Great Britain, they may be most conveniently studied with reference to three districts in which they are chiefly developed, and which may be called respectively the *Cumbrian*, (occurring in the lake district of Cumberland and Westmoreland,) the *Cambrian* or North Welsh, and the *Silurian*.* It is not at all easy to ascertain, however, which are really the contemporaneous strata in the two systems of Cumberland and North Wales, because of the extreme complexity of all the phenomena presented by them, and the total absence of groups of fossils which can be considered accurately characteristic. These two systems, described by Professor Sedgwick, together with the Silurian system of Mr. Murchison, form a series of strata extremely remarkable for their vast thickness, and the complications of disturbance by which they have been affected in the northern and western parts of Great Britain.

THE CUMBRIAN SERIES.

The granite of Skiddaw may be taken as, on the whole, the best starting point for English Geology; it forms what may be called the mineral axis of the Cumbrian mountains, and is there overlaid by a distinct class of rocks, highly crystalline in their structure, and almost without calcareous matter, which pass upwards into a fine dark glossy clay-slate.†

* See chapter iii. page 99.

† This, and some other terms chiefly referring to rocks mineralised by the action of heat, will be explained in a future chapter when describing the igneous and altered rocks. They will not often occur in this first part of the subject; but in speaking of the lowest strata it is necessary to allude to them.

Above the clay-slate in Cumberland there exists a group of quartzose and chloritic roofing slates of mechanical origin, but alternating with innumerable igneous rocks which partake of all the accidents of the slates. This group is of enormous thickness, and abounds in calcareous matter, but has no beds of limestones, and no organic remains. It is chiefly developed on the south flanks of the Cumberland mountains, but is also found on the north side, and is overlaid by calcareous fossiliferous slates. "The fossiliferous slates, however, of North Wales, belonging to the same period, are of much greater thickness than those in Cumberland, where also the fossils end at the commencement of the porphyries, and represent the *Caradoc Sandstone* (of the Lower Silurian system), and that only, in the most limited sense of the word. In Wales, on the other hand, there are many thousand feet of fossiliferous strata, alternating with the porphyries, below the geological level of the Coniston limestone, (the rock overlying the fossiliferous slates,) and containing some fossils (*e. g.* Asaphus buchii) which have not been seen in Cumberland and Westmoreland sections."

The upper portion of the Cumbrian series, commencing with these calcareous slates, (exhibited at Coniston Water Head and Kirby Ireleth,) are gradually replaced by other slates and hard flagstones, which occasionally pass into thick sandy beds of the rock called *grauwacké*.* "These beds are ill defined both at their upper and lower limits, passing by insensible gradations and without any distinct bands of limestone into the overlying rocks, which contain fossils of a more recent date (Upper Silurian). Indeed, so complete is the passage that many beds formerly con-

* *Grauwacké* (*grey-wacké*) a name originally applied by the Germans to a peculiar grey micaceous sandstone, often fissile, extremely abundant in some parts of the Continent, and of different geological periods.

sidered as belonging to the lower division of the fossiliferous slates of Westmoreland and Cumberland, are now proved to belong to the upper division, so that the true representatives of the Lower Silurian rocks of Mr. Murchison, will occupy a comparatively narrow zone on the geological maps of this part of England."

THE CAMBRIAN SERIES.

The true passage, from the crystalline and non-fossiliferous rocks to the overlying stratified formations must apparently be sought for in the old slate series of Caernarvonshire and Merionethshire; where bands of porphyry and felspar rock alternate indefinitely with beds of mechanical origin; and where, through wide tracts of country, a few corals, encrinites, and bivalve shells, are sparingly distributed. This group is of enormous but unknown thickness, and the beds are bent into great undulations, the anticlinal and synclinal lines being parallel to the strike of the chain.

"In following the ascending sections from these beds, we at length reach several bands of limestone and other beds, which contain fossils in great abundance. Three or four of such bands are seen near Bala, and strike through all the southern end of the Berwyn mountains." The fossils from these calcareous beds near Bala resemble those of the Cumbrian calcareous slates, and the limestones of Coniston Water-head.

The Bala limestones may be considered as the base of the upper part of the Cambrian group, which also passes into and is identical with the Lower Silurian formations of Mr. Murchison, the fossils being essentially the same; and, enormously as this series is extended in a vertical direc-

tion, there seems no way of effecting a subdivision by any other considerations than those of local or mineral peculiarities, as the fossils of the upper and lower portions do not differ sufficiently to justify any separate grouping on palæontological grounds.*

In many parts of Wales there are considerable faults, separating the beds I have described from those of the Silurian group, described by Mr. Murchison; but at the north end of the Berwyn chain they appear to pass, by insensible gradations, into the Caradoc sandstones, and through them into the Upper Silurian rocks.

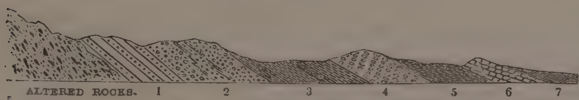
The upper division of the slate rocks in North Wales, as in Cumberland, belongs to the Upper Silurian system of Mr. Murchison. It is made up of great thicknesses of flagstone, (the Denbigh flagstone,) which extend to the mountain limestone, and which seem to admit of three subdivisions, all of them fossiliferous, and the upper beds passing into shales and rotten slate. These groups do not closely resemble in mineral structure the corresponding beds in Westmoreland, and they are still farther removed from the Upper Silurian beds in Shropshire and South Wales; but they have been compared, by Professor Sedgwick, with the fossiliferous slates and flagstones of Horton and Settle, in Yorkshire.†

* "So many species are found from top to bottom, that at present I know not how to split up the Protozoic rocks into two or more divisions."

† "At the south-western end of the Cumbrian mountains, a gradual passage may be traced (as above stated) from the upper to the lower fossiliferous slates. In North Wales the Upper Silurian rocks appear in many places to be unconformable to the lower, although there, also, the line of demarcation between the two series is occasionally doubtful, owing to the presence of passage beds of an intermediate type. It will be seen in the next chapter, that the separation between the upper and lower parts of the Silurian system is, on the whole, clearly defined in the country described by Mr. Murchison."

CHAPTER III.

ESTABLISHMENT OF THE SILURIAN SYSTEM BY MR. MURCHISON.—THE LOWER SILURIAN ROCKS.



ORDER OF SUPERPOSITION OF THE SILURIAN ROCKS.

I HAVE had occasion, more than once, in speaking of the rocks of Wales, to make use of the term "*Silurian*," as applied to formations of a certain date. It will be proper here to give a brief account of the history of that name, and the nature and extent of the strata which, in England, are designated by it.

Up to the year 1830, Geologists were not aware of the existence of any complete series of stratified rocks below the sandy beds which underlie the mountain limestone formation, and which were called "old red sandstone;" and although there were certain limestones of greater antiquity than any of those of the carboniferous system, still no regularly deposited and continuous formations had yet been described.

* 7. Upper Ludlow shale . . .	Ludlow series	Upper Silurian.
6. Aymestry or Ludlow limestone		
5. Lower Ludlow shale . . .		
4. Wenlock limestone	Wenlock series	
3. Wenlock shale		
2. Caradoc sandstone	. . . . . .	Lower Silurian.
1. Llandeilo flags		

The cause of this appears to have been, that the true and full sequence of the older rocks is very rarely exhibited; and, in the absence of such distinct knowledge, it was impossible to make out the extremely complicated structure of those parts of England, Wales, and the continent of Europe, in which an interrupted series is exhibited. The rocks of Devonshire and Cornwall, for instance, were assumed to be of the earliest period, because in contact with granite, and presenting the peculiar structure of the oldest rocks in their numerous slaty beds; but some of their fossils were more like the fossils of the mountain limestone than those derived from many well known fossiliferous slates and limestones of an older date, and thus they presented a stumbling-block extremely difficult to overcome.

In other parts of the country also the same difficulties presented themselves. In Scotland, where the old red sandstone occupies a most important place in the geological sequence, it appears to have no relation whatever to any lower fossiliferous strata; while in Cumberland and North Wales, although such relation exists, it is in so confused and distorted a condition as to be absolutely incomprehensible; unless viewed and examined with the aid of a key, furnished by an accurate knowledge of some less disturbed district.

It was under these circumstances, with regard to the geology of the older rocks, that Professor Sedgwick went to Scotland in the year above-mentioned (1830), for the express purpose of seeking for beds to connect the old red sandstone, the supposed base of the mountain limestone, with the fossiliferous *grauwacké;* but the total absence of such beds rendered a successful result impossible. In 1831, Professor Sedgwick, again in search of the sequence

so much wished for, entered North Wales, induced by Mr. Greenough's Geological Map of England, to seek for its existence in Denbighshire, where, indeed, as already observed, (p. 99,) it may be traced, although it is very imperfect and obscure, the beds of the old red sandstone resting unconformably on the Silurian rocks. Accustomed to the peculiar condition of the strata in the north of England, Professor Sedgwick there found, as he observes, "*Westmoreland over again.*"

In the same summer Mr. Murchison, wishing to study the sequence beneath the old red sandstone, entered Wales by the Wye, and on its banks he first discovered the fossiliferous strata which clearly connect that deposit (the old red sandstone) with the inferior slaty rocks. He then traced these strata from Brecknockshire, Radnorshire, to Herefordshire and Salop, and thus discovered those perfect sections, perhaps the clearest and best in the world, which, having found, he made emphatically his own, and so formed the groundwork of that first great step in geological science, the establishment of a secure base from which to construct an ascending and descending series of the old rocks.

At the close of the summer of 1833, the first general sketch of the order of these formations was made known to the world; and a definite notion given of an extensive series of fossiliferous rocks, older than the old red sandstone, but passing upwards, by insensible gradations, into the lower beds of that formation.

Extending his researches in various directions, Mr. Murchison soon recognised in this large and ancient group of strata, such peculiar organic remains, such distinctness of physical and lithological structure, and such well-defined subdivisions, marking the order of superposition, that he

felt it was entitled to be considered a separate system, and be distinguished by a collective name.* He therefore selected one derived from the geographical position of the most perfectly developed rocks in the series; and these, occupying the region formerly ruled by the ancient "Silures," or, in other words, the "Silurian region," he has called the series of rocks the Silurian System;—a distinctive name expressing the fact, that in this Silurian district, the existence of a complete succession of fossiliferous strata, interpolated between the oldest slaty rocks and the old red sandstone, was for the first time observed. Such then was the original meaning of the term "*Silurian*," and in this sense it has been made use of to indicate strata occupying a certain geological position, whether occurring in our own country, or in other lands; and whether the lithological subdivisions, which were first observed in Siluria, are represented or not by similar subdivisions in other places,

The whole series of the Silurian rocks of England has been separated by Mr. Murchison into two divisions, the Lower and the Upper; but this subdivision having been made with reference to the developement of the rocks in a comparatively limited district, and on the supposition that that there was a distinct base for the lower system, which really does not exist, it is only the upper system that can be looked upon as well defined.† I shall, therefore,

* *Vide* "The Silurian System," &c. p. 6.

† It must be admitted, that this question of a base line is still in some respects *sub judice;* for while, on the one hand, Professor Sedgwick contends that it would have been more consistent with the geology of Wales to have closed the Silurian system with the Wenlock shale; Mr. Murchison, on the other hand, supported by the opinion of Sir H. De la Beche, considers it proved, that in Caermarthenshire there are not only no rocks lower than the Lower Silurians, but that, physically, the strata are the *same* folding over from the Silurian zone, and extending to the Atlantic sea.

speak of the "Lower Silurian Rocks," in this chapter, merely to explain the geology of the district in which its two members, the *Llandeilo flags* and the *Caradoc sandstone*, are so finely exhibited.

The base of the system, as recognised by Mr. Murchison in the Silurian region, consists of a series of hard, dark-coloured, sandy, or gritty beds, readily splitting into flag-stones; which are largely developed near the town of Llandeilo in Caermarthenshire, and are thence called *Llandeilo flags*. These beds are slightly micaceous, and frequently so calcareous as to contain true limestones. They rest upon the older strata of the Cambrian series, and sometimes replace them,—the transition taking place by almost insensible gradations.

Next to them in order, and resting conformably on these flagstones, there is found throughout the Silurian region, and exhibited more especially on the slopes of Caer-Caradoc, an extensive range of fossiliferous sandstones, with calcareous bands, denominated "*the Caradoc sandstone*" (diagram, p. 99), and forming the upper portion of the lower Silurian group.

As might be supposed, from the description already given of these beds, their mineral structure and lithological character is variable: but, where the sections are best exhibited, there occurs in the lower part of the group a deep, reddish purple sandstone, mixed with clay, and marked with greenish streaks. Calcareous bands, exceedingly fossiliferous and sometimes burnt for lime, succeed to these, and alternate with sandy and pebbly gritstones; the upper grits being of a reddish brown or yellow colour, and overlaid by thick-bedded, finely-grained, siliceous sandstones, much quarried for flags and building stone. Irregular patches and occasional courses of limestone are dis-

tributed through this rock and three or four hundred feet of flaggy beds succeed, composed of fine grained sandstone of a green colour, and slightly micaceous. These latter beds are fossiliferous and finely laminated; but they are almost entirely devoid of argillaceous matter.

The uppermost beds of Caradoc sandstone are also micaceous and thinly laminated, containing bands of impure sandy limestone, and thin courses of sandstones full of shells and fragments of shells. In these beds, for the last time, we find the fossils characteristic of the lower part of the series; and, on the other hand, several species make their appearance, common in the Upper Silurian rocks. Throughout the whole series, however, the fossils found are those only of invertebrata; and no remains have yet been discovered of any species of vertebrated animals occurring in these lower strata.

The older fossiliferous strata, which we have been considering in the last two chapters, and which together form the Protozoic group of Professor Sedgwick,* may be stated as consisting on the whole of beds highly argillaceous or clayey, succeeded by others almost exclusively arenaceous or sandy; the clay being usually changed into slates or shales, with cleavage planes, and the sand forming sandstones, usually fissile or splitting readily in consequence of the presence of mica distributed through the whole to a greater or less extent.

But these sandy and clayey beds are not without occasional interruptions, caused by the intervention of cal-

* Mr. Murchison, however, had previously used the term "Protozoic," applying it to Silurian fossils generally, because he then supposed the animals whose remains were there discovered to have been the most ancient inhabitants of the earth. Subsequent researches in various parts of the world, as well as in South Wales, have shown that the term, if applied at all, belongs rather to the older division of the older Palæozoic period.

careous bands, or rather, lumps of calcareous matter, which become gradually more abundant and more extensive as we approach the newer type; and it is chiefly in these lumps that the fossils are found which characterise the formation. In Merionethshire, however, and in Snowdonia, (the district of Snowdon,) slaty masses of great thickness contain, in different places, fossil bands, or are themselves fossiliferous; and it has been well ascertained that there are several thousand feet of these below the Bala limestone.

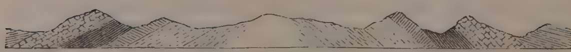
Throughout this vast extent of vertical thickness many species, and groups of species, are perfectly continuous; and the Cumbrian and Cambrian strata are not characterised by fossils which separate them from the Lower Silurian rocks. The zoological type of these latter strata is thus shown to be the oldest that can be detected in North Wales, which is, beyond a doubt, that country of all others in Europe, hitherto described, where there is the most complete developement of the inferior strata.*

* I cannot conclude this chapter without acknowledging the great assistance I have received, both in it and the former one, from the kindness of Professor Sedgwick and Mr. Murchison. For those paragraphs marked with inverted commas I am entirely indebted to the former, and I may venture to quote his authority for the historical introduction to the present chapter: to the latter I am also bound to express my best thanks for the valuable and important hints as well as for the direct information he has communicated.

CHAPTER IV.

UPPER SILURIAN ROCKS.

HAUGH WOOD.



SECTION ACROSS THE VALLEY OF ELEVATION AT WOOLHOPE.*

The Upper Silurian rocks of England are chiefly developed in the counties of Shropshire, Radnorshire, and Herefordshire,† and are well seen in a remarkable valley of elevation at Woolhope in the latter county, a section across which is represented in the accompanying diagram. In the valley of Woolhope it must not be expected that the beds exhibit their greatest thickness, or their most characteristic peculiarities; but the sequence is very well shown; and from the centre of Haugh Wood the eye ranges across a double circle of hills with intermediate valleys, the view extending also to the plain of the sandstone beyond.

A little investigation will soon show that these hills consist of limestone, the intermediate valleys of soft, shaly beds, and the central hill of sandstone. The central sand-

* For references see the next page, or diagram, p. 99.

† Mr. Murchison has also shown that they range continuously through Brecon, Caermarthen, and Pembroke, in the last-mentioned of which counties he defined them in the sea cliffs of Marloes Bay, as being surmounted by old red sandstone, and as having a copious base of Lower Silurian rocks, (both Caradoc and Llandeilo,) charged with typical fossils. (See Sil. Syst. p. 392 et seq.)

stone is that of the Lower Silurian group, or the Caradoc sandstone; and the beds wrapped round it form the series of the Upper Silurian rocks.

The whole group, as found in the typical Silurian district of Salop and Hereford, is readily subdivided into two parts, according to the following table (see also diagram p. 99):—

Upper Silurian Rocks.	Ludlow Formation	7. Upper Ludlow Shale.
		6. Aymestry Limestone.
		5. Lower Ludlow Shale.
	Wenlock Formation	4. Wenlock Limestone.
		3. Wenlock Shale.

The *Wenlock shale* (3), sometimes called the Dudley shale, consists of a great developement of dirty-looking argillaceous beds, rarely micaceous, and containing, here and there, a few lumps of impure argillaceous limestone. The colour of these beds varies from a pale grey to dark grey or black; and, according to Mr. Murchison, the line of separation between the Upper and Lower Silurian beds is best drawn where the hard sandy, and sometimes calcareous strata, at the top of the Caradoc sandstone, are succeeded by these softer shales (diagram p. 99). Calcareous concretions are met with occasionally, both in the lower and upper portions, and the laminæ of deposit are not unfrequently indicated by large spheroidal lumps; but the central beds are soft, incoherent, and easily washed away, an instance of which is seen along the escarpment of Wenlock edge, where the deep valleys, between that ridge and the Caradoc hills, indicate the extent of denudation that has taken place in this part of the series.

The *Wenlock* or *Dudley limestone* (4) forms, in some tracts, the most prominent feature in the geology of this lower division of the Upper Silurian strata, and is admirably exhibited in the rock on which Dudley Castle is so

picturesquely placed, and also in the beautiful escarpment of Wenlock edge. The remarkable physical features of this bed of limestone, and the singular abundance of fossils in both localities mentioned, — the organic remains being also quite peculiar to the older rocks,—render it not a little extraordinary that so interesting part of the geology of England should have been so long left undescribed.

The Wenlock limestone formation rests conformably on the Wenlock shale, and is made up chiefly of concretions of argillaceous limestone, extremely fossiliferous, separated from one another by beds of shale.

The concretions are massive, and valuable for lime-burning, the best of them being quarried to a considerable extent. They are of irregular thickness and magnitude, and are surrounded and enclosed by beds of impure clay and shale; the clay entering into the innumerable interstices and crevices of the limestone, and giving it a singular mottled appearance.

Occasionally, however, beds of argillaceous limestone alternate with shale; and at Wenlock Edge, and elsewhere, the whole series is both overlaid and underlaid by a number of small concretionary nodules of grey limestone, running in layers, and held together by shale, with which the nodules sometimes unite, and form irregular and thin beds of lenticular limestone.

The nodules, so common in the Wenlock limestone, are found also in other parts of the formation, and are usually crystalline, and full of corals and encrinites; the whole group of the Wenlock series, indeed, may be said to consist of numerous concretionary masses, separated from each other by a vast predominance of argillaceous matter.

Of the Ludlow formation, the lower bed—the *Lower*

Ludlow shale (5)—resembles, in colour, appearance, and want of cohesion, the middle shales of the Wenlock group, and occurs in valleys, between the Wenlock and Aymestry limestone. The steep escarpments of several hills west of Ludlow expose the outcrop of the strata; and their junction with the underlying Wenlock limestone is marked by a series of friable stone-bands, containing corals and spheroidal concretions of clayey limestone, alternating with beds of clay. The concretionary character of the lower part of the series is very remarkable; and the concretions are almost invariably formed upon some organic body as a centre.

The main portion of the Lower Ludlow formation is composed of dirty shales, locally called *mudstones;* but these shales change towards the upper part, and become slightly calcareous. They are then succeeded by sandy flag-stones, also containing calcareous matter, and are separated by courses of soapy clay, (sometimes used as fullers earth,) from the overlying beds of limestone.

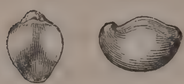
The *Aymestry* or *Ludlow limestone* (6) differs considerably from the Wenlock limestone, both in its general appearance, and in its having a less concretionary structure. It is sub-crystalline and highly fossiliferous, and is fully developed near the village of Aymestry, in beds from one to five feet thick, which are of an indigo, or bluish-grey colour, mottled with white, and contain numerous layers of shells and corals. Near the village of Downton-on-the-Rock, this limestone is well seen in a vertical cliff, the beds dipping at an angle of about 25° N., and being not less than fifty feet in thickness.

This intermediate calcareous band is frequently absent in localities where the other portions of the Ludlow formation appear; but, when present, it may usually be identified as

well by its lithological peculiarities as by a remarkable fossil, (*Pentamerus Knightii,*) characteristic of it.

PENTAMERUS KNIGHTII. Sil. Syst. *Aymestry Limestone.*

The Aymestry limestone sometimes passes, by a series of gradual changes scarcely perceptible, into the lower beds of the *Upper Ludlow formation* (7), and may even be grouped with them when they happen to be concretionary and calcareous. These lower beds are, however, much more frequently argillaceous, and well entitled to the name of *mudstone*, which is often applied to them, as well as to the Lower Ludlow shales. It is usually only the transition beds from the underlying limestone, that are at all calcareous; and these are also remarkable for being absolutely loaded with the shells of a species of Brachiopoda, (*Terebratula navicula,*) which is exceedingly common wherever this rock makes its appearance.



TEREBRATULA NAVICULA. Sil. Syst. *Ludlow Rock.*

The central mass of the Upper Ludlow formation is made up of strata, containing more calcareous matter than the lower shales; and this imperfect limestone, being mixed with an argillaceous paste, forms a tolerably durable building stone. The best stone quarried for such purpose occurs in beds not exceeding eight inches in thickness; and its surface is frequently marked by undulating ridges and furrows, supposed to be due to the rippling action of the waves, when the bed formed the surface-bottom of the sea,

and the sediment was still soft. Markings, resembling those which would be made by the passage of the smaller marine animals over sand and mud, are also common on these furrowed surfaces.

The upper beds of the Upper Ludlow rock—those, therefore, which form the uppermost and newest of the Silurian system—consist chiefly of yellowish sandstones of very fine grain, and slightly micaceous, which succeed the calcareous strata just described, with the intervention of a greyish coloured stone. Near Downton Castle there is a bed of greenish-grey argillaceous sandstone, resting on these sandy and flaggy beds, and almost made up of the remains of fucoids, and the columns of some soft zoophyte, which is overlaid by another fossiliferous bed, seldom exceeding a few inches in thickness, and occasionally dwindling to a quarter of an inch. This singular stratum is a matted mass of the scales, defensive fins, jaws, teeth, and coprolites of fishes,* united together, with a few small shells, by a cement in which variable proportions of carbonate of lime, iron, phosphate of lime, and bitumen are disseminated. Above this, again, a succession of micaceous sandstones passes insensibly into the lower beds of the old red sandstone, and completes the series of Silurian strata.

The general character of the Ludlow rocks in other districts—as, for instance, near Llangollen, in North Wales—is chiefly derived from the micaceous sandstones, which retain the same appearance and the same fossils† as in the Silurian region. All the minuter subdivisions are no doubt very local; but they are so beautifully marked in

* The Wenlock beds also contain the fossilized palatal bones of fishes. They were first discovered by the Rev. P. B. Brodie, and have hitherto only been found in one spot.

† *e. g. Terebratula navicula,* extremely abundant on the hill called Dinas Bran, near Llangollen.

the true Silurian district, as to be well worthy of the particular notice devoted to them.

In the north of England, as I have already observed, the upper part of the Silurian system is exhibited in a series of sandy flagstones, with imperfect slaty bands, based on calcareous slates and the limestone of Coniston Water-Head. The slaty bands are sometimes calcareous, but do not contain limestone fit for use; and the series terminates with red fossiliferous strata, the fossils occurring in concretions of limestone, and the whole being overlaid by the marls of the old red sandstone. The Silurian group, in this district, although repeated by several undulations, is still of great thickness, and contains several fossils peculiar to it, although the greatest portion are of known Upper Silurian types.

On the whole, then, it appears, that certain common lithological characters pervade most of the strata of the Upper Silurian formations in England; but that, while the subdivisions established by Mr. Murchison are persistent throughout a large tract of Shropshire, Radnorshire, and Herefordshire, their lithological details, as might indeed have been anticipated, do not apply to other and distant parts of the country. In the Silurian district the total thickness of the two formations (the Wenlock and Ludlow) is very considerable, and it is probably much greater in some parts of North Wales; while the beds throughout exhibit every appearance of slow deposition in the finely laminated shales and micaceous fossiliferous sandstones which abound in them. When it is considered that the sketch now given of the British Silurian rocks presents a well ordered succession of strata of very great thickness, each subdivision being characterised, by a corresponding suite of organic remains; and that until Mr.

Murchison undertook to investigate their order of superposition, all these were considered as one group without definite sequence, and were passed over almost without notice or description; the value of that gentleman's researches in English Geology may be in some measure appreciated.*

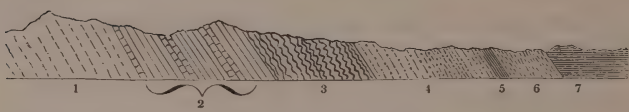
His labours, in short, established securely a base line from which both ascending and descending sections could be safely constructed. The first great result from the establishment of this base line was, the determination of the true geological place of the older fossiliferous rocks of Devonshire and Cornwall.

* In the next chapter it will be seen how immediate and important were their results, also, on Foreign Geology, where the application of the Silurian System has been, on the whole (particularly in America and Russia), even more useful than in England.

HARLECH CASTLE, MERIONETHSHIRE.

CHAPTER V.

THE FOREIGN ROCKS OF THE SILURIAN PERIOD.



GENERAL ORDER OF SUPERPOSITION IN GERMANY AND BELGIUM.*

The series of strata in other parts of the world, contemporary with the lower and older portion of the Palæozoic group of England, was not likely to exhibit the same subdivisions as those found to obtain in our own island. In fact, wherever they have been examined and described, they seem to lie either in great and unbroken masses, in which the sequence is continuous, but palæontological evidence wanting; or in extensive but indeterminable series, partly fossiliferous, but passing into lower and non-fossiliferous strata, without offering any means by which they may be compared with other series of similar lithological character supposed to be contemporaneous with them.

* 7. Calcareous shales of the Devonian period.
6. Slaty schists and shales. Lower Eifel.
5. Wissenbach slates.
4. Grauwacké flagstones.
3. Slaty flagstones. Ems, Ehrenbreitstein, and near Elberfeldt.
2. Slates with a few limestone bands and a few fossils. The Taunus.
1. Quartzose beds, grits, and shales of the Ardennes:—non-fossiliferous.

But, although there are great difficulties to be overcome in the classification of these rocks, it is interesting to know, that of the broad facts concerning their order of superposition, and their actual contemporaneity with the Silurian and sub-silurian strata of our own country, there is less doubt than in similar identifications in many other formations; for the fossils that are found are so peculiar, and are so nearly the same throughout, that when once a familiar knowledge of their general character and appearance is attained, and the eye is accustomed to their forms, they are easily and readily recognised. The transition from one to another in the continental beds of the period under consideration, is, however, more gradual, and less strikingly marked by differences of fossil forms through an extensive vertical range, than is the case in England; and our own country furnishes the key, without which many extensive tracks could hardly be brought into relation with each other, or with newer formations.

The older Palæozoic rocks of the continent are chiefly found in Northern Europe; and Westphalia, Belgium, some parts of Russia, and Scandinavia, are those districts where they seem to possess the greatest interest, and have the widest range.

In Westphalia, and along the right bank of the Rhine, it has long been known that there is a vast developement of schistose and grauwacké rocks, with occasional calcareous beds, the whole having either been forced up in a dome-shaped form through formations of a much more modern date, or greatly disturbed and dislocated together with the newer rocks, in consequence of the numerous and violent subterraneous movements that appear to have affected that part of Europe. A few years ago Professor Sedgwick and Mr. Murchison, having made themselves acquainted with

the order of superposition of the older rocks in England, visited the supposed contemporaneous beds of Germany and Belgium; and the account of their visit, published in the Transactions of the Geological Society (vol. vi. p. 222), is the only source from which, at present, any accurate knowledge of the structure of the Palæozoic rocks of this part of the continent is to be derived.

According to these authors, the succession consists in general of thin-bedded schistose grauwacké passing into quartzose sandstones, having more or less the character of micaceous flagstones, and separated occasionally by seams of impure limestone.*

In the northern part of the Duchy of Nassau, near the town of Dillenburg, there occurs a remarkable fossiliferous slate, which, both by its position and the fossils it contains, evidently corresponds to the Upper Silurian beds; and there exists the clearest proof, from the consistent evidence of sections, that the strata which form the greater part of the immense grauwacké system of the Rhine underlie this slate. But the attempt to separate the grauwacké into formations is met by difficulties which appear almost insurmountable; for there are no calcareous bands, characterised by peculiar fossils, as in England, and the same species of fossils are found in all parts of an enormous vertical thickness of strata.

The Silurian rocks, then, are developed to a great extent in this part of the continent, and in thick beds: they are marked by certain fossils, which are so widely spread as to prove the long duration, and extensive range, of some, at least, of the races of animals living during those

* See diagram p. 114, a portion of the general section given in the paper of Messrs. Sedgwick and Murchison. Trans. Geol. Soc. 2nd Series, vol. vi. pl. 23. fig. 1.

early periods ;. but the state of the developement of the different strata does not admit of their being subdivided into well-marked physical groups; and, hence, they are much less distinct than in the contemporaneous formations in England.

In Belgium, the non-fossiliferous slate of the Ardennes forms the first term of a series which, by imperceptible changes in lithological character, and by the gradual introduction of fossils peculiar to the oldest formations, passes into Silurian strata, which wrap round the central and crystalline slates, and appear, from the evidence of their fossils, to belong to the Upper Silurian rocks of England.

In Bohemia, the older rocks, which do not appear beneath the Devonian and carboniferous strata of the north-east of Bavaria and the Saxon states, are again observable, and in a greyish sand or grauwacké, near Prague, fossils have been found of the Lower Silurian period.* These are again repeated in Silesia, and in this way a passage is established across the continent connecting the Silurian rocks of our own island, through the disturbed Westphalian series, with the almost horizontal contemporaneous beds in the north-east of Europe.

The oldest sedimentary deposits of Russia, (those on which St. Petersburgh is situated,) are described by Mr. Murchison† as composed of clays, sandstones, limestone, and flagstone; which rest upon gneiss and altered rocks, and, from their position and organic remains, are to be considered the equivalents of the Silurian system of England.

In the blue clay, which forms the lowest stratum in the Russian palæozoic series, no organic remains have yet

* Proceedings of Geol. Soc. vol. 3, p. 167. † Ibid. p. 399.

been found, and the first fossiliferous bed is a sandstone, or grit, distinguished by a remarkable fossil (the *Ungulite*) unknown in Western Europe, but, in the overlying limestones, and the flagstones which rest upon them, other organic remains abound, and the subdivisions agree tolerably well, in their leading characters, with those established in our own country.

With the exception of trifling dislocations, the Silurian rocks of Russia are so uniformly horizontal that the dip in some places amounts to only 2° or 3°, and in a quarry visited by Mr. Murchison, its direction was observed by pouring water on the surface of the rocks; but, notwithstanding this nearly perfect horizontality, there may clearly be traced, in the Baltic provinces of Russia, a passage from the lowest beds in the north to the higher ones in the south, where they are surmounted by others of still newer date.

The horizontal position of these Russian beds would seem to have been incompatible with any very great thickness; but the superficial extent to which they may be traced is considerable, and they appear to occupy a tract at least as large as the principality of Wales.* They increase in thickness as they approach the western boundary of the Russian empire, and pass into Scandinavia.

The Norwegian rocks resemble, both in mineral character and in fossils, the lower strata of the English Silurian system. At Christiana there is a group, con-

* "The Silurian rocks in the Ural mountains, where they are regularly surmounted by the Devonian and carboniferous systems, are of much greater thickness than in the Baltic provinces of Russia, and also of much more diversified lithological structure. Together with certain metamorphic and igneous rocks, they occupy the axis of that chain throughout 18 degrees of latitude."—*Note by Mr. Murchison.* They will be fully described in the forthcoming work of Mr. Murchison and his associates.

sisting of dark shale, slate and clay, with calcareous bands and gritstones overlying them, and passing upwards into strata of limestone, which abound in corals, and of sandstone, shale, and conglomerate. The whole series contains fossils identical with those found in the Caradoc sandstone, and the Llandeilo flags: and Mr. Lyell has observed that, at no great distance, there exists a limestone rich in fossils, several species of which were of Upper Silurian types, and others common to both the Upper and Lower Silurian; he is, therefore, inclined to consider these beds as forming a passage between the lower and upper portions of the older palæozoic group.

The thickness of the beds in Norway, Sweden, and Gothland is much greater than in Russia, but gradually diminishes towards the junction; and the rocks lose many of their characteristic fossils.

France, again, is not without rocks of the earliest palæozoic period, and in Brittany, more particularly, they are developed to some extent; but there is little that requires detailed description.

In the south of Europe the remains of rocks of this ancient period are exceedingly rare, but they have been found to exist in the neighbourhood of the Thracian Bosphorus, not far from Constantinople. Mr. Strickland* has described from this locality a mass of argillaceous schist (sometimes exhibiting slaty cleavage), compact brown sandstone, and dark blue limestone, all of which pass into one another by insensible gradations. From the nature of the fossils, which, however, are very rare, these rocks seem to be on a parallel with some of the passage beds, uniting the Lower with the Upper Silurian groups in Westphalia and Belgium.

* Trans. of Geol. Soc., 2d ser. vol. v. p. 385.

In North America the older rocks are expanded to a vast extent, and are of great thickness in many districts to the north and west. One group, indeed, of beds of shale, limestone, and marl, in the great valley of the Ohio, is estimated to occupy a surface of 10,000 square miles; and, by the evidence of fossils, the whole is referred to the earlier palæozoic period. These strata are covered by compact limestone and shale, of great thickness, and are said to exhibit proofs of contemporaneity with the Ludlow series. Many other parts of North America are remarkable for the extent to which the oldest fossiliferous rocks have been there developed; and the similarity of the organic remains to European fossils communicates an additional interest to the geology of these extensive groups.

Even in the extreme south of this great western continent, in Tierra del Fuego, and the Falkland islands, similar phenomena have been observed, and some fossils obtained by Mr. Darwin from these localities can hardly be distinguished from species found in the Silurian rocks of England.*

It would appear, also, from recent observations, that the lowest strata in New Holland exhibit the same fossils as those found in England; and they are bedded in a coarse ferruginous sandstone, slightly micaceous, and not at all unlike the *grauwacké* of German geologists.†

Having now arrived at the close of the older palæozoic period, let us pause for a moment before passing to the

* Darwin, Voyage of Beagle, p. 253.

† True Silurian fossils have also been obtained from Southern Africa, by the Rev. W. B. Clarke, and are described by Mr. Murchison. *Vide* "Silurian System," p. 583.—"Proceedings of Geol. Soc.," vol. 3, p. 421, and again, p. 644.

consideration of the fossil remains, and look back upon the collective extent of those formations which have passed in review before us.

Commencing with the crystalline and altered slates of Cumberland and North Wales, it may be observed that the proportion of argillaceous matter and quartz in these first formed beds is, beyond all comparision, greater, and the mixture with calcareous rocks less, than in strata of more recent date. Although of a thickness amounting to many thousand feet, the vast series of sedimentary deposits, occurring below the assumed base of the Silurian system, may be said to be, almost without exception, composed of clay and flinty sand, in which the mineral character is constantly apparent; while the presence of mica seems to indicate, beyond the possibility of doubt, a vast preponderance of granitic rocks amongst those to whose degradation and disintegration this long series of crystalline slates, mica-schists, micaceous sandstones, and quartz rock, must be owing.

The unvaried character of these beds over large tracts of country, and the general resemblance that obtains everywhere among the oldest sedimentary deposits, cannot but be looked upon as a strong argument in favour of the uniformity of the materials of which the original framework of the solid surface of the globe was composed. It must be remembered, too, that we recognise no such appearance of uniformity in the igneous and altered rocks of more modern date, nor in the metamorphic rocks of the Alps, or other mountain districts, which, indeed, show no indications that can assist us in determining the conditions under which the formation of strata, resembling the sub-silurian rocks, would be possible. It is the opinion of Professor Sedgwick, (whose familiar acquaintance with all the geological

phenomena of the lake district, combined with his profound knowledge of crystalline and altered rocks, render him certainly the best qualified of any Geologist to offer an opinion,) that the abundance of igneous rocks associated with slates of mechanical origin in Cumberland and Westmoreland, and the manner in which they alternate, can only be explained by assuming that outbursts of molten rock were repeated, from time to time, from beneath the bottom of the sea, during the whole period of the formation of many thousand feet of strata. Such a succession of volcanic eruptions, and to such an extent, would seem to be totally unparalleled during the deposit of the secondary strata of our Isles; nor is anything of the kind observable in rocks of still more recent date.*

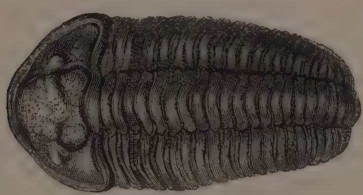
At the same time, and while this extraordinary action was going on, other parts of the ancient seas were the scene of quiet uninterrupted deposits; but in every case the general character of the beds deposited was the same; and even in the rocks which form the base of the Silurian system, where the micaceous and sandy flags contain a few calcareous bands and a moderately large proportion of carbonate of lime, we can easily recognise the materials of decomposed granite, originally formed into beds of gneiss and mica schist and then employed in the composition of these quartzose and micaceous, but sedimentary and fossiliferous, rocks.

On the whole, the history of the sub-silurian period is one of unquiet and restless agitation and change, but apparently of rapid deposit; and if, in these strata, we do not see the actual rocks first formed by the action of water

* "I think the alternations of igneous rocks, described by Mr. Hamilton as occurring in Asia Minor, most nearly resemble those observed in Cumberland, but in the latter case the melted matter was poured out at the bottom of the sea."

upon the earth, we are at least introduced to a knowledge of formations more uniform in their character, more extensive in the area over which they are deposited, and of a thickness enormously greater, than is the case with the other and newer palæozoic formations; and the contrast is still more striking when we bring them into comparison with any groups of strata formed during the later secondary, or the tertiary period.

The beds of the Upper Silurian system, from the Lower Wenlock to the Upper Ludlow shales, present, amidst all the disturbances by which they have been affected, an appearance of having been deposited in seas more tranquil on the whole than those of the earlier period; and they exhibit a distinct lithological character, in which the presence of a considerable quantity of carbonate of lime is a peculiarity, not more strikingly seen in the Silurian strata of England than in the contemporaneous rocks of Sweden and Norway, of Russia, and also of North America. The coralline limestones of this period offer sufficient proof that a change had taken place; although the conditions which governed the duration of species upon the globe, had not yet been brought into action so completely as to efface the marks of the preceding and earliest period.



CALYMENE BLUMENBACHII.

CHAPTER VI.

THE FOSSILS OF THE OLDER PALÆOZOIC PERIOD.

Amongst the fossils of the extensive series of formations which I have classed together, under the general name of Palæozoic, there will be found many gradual, but not unimportant, modifications of the conditions of animal and vegetable life; and for this reason it will be expedient to follow the same order as that adopted in describing the rock formations, grouping the whole into three principal divisions. I may observe also here, that the Palæontology of the sub-silurian or Protozoic strata is not sufficiently distinct from that of the overlying formations to render a separate account of them necessary.

I shall not, however, attempt to enter upon any detailed account of species in describing these fossils, nor shall I offer any special remarks on those which may be peculiar to each distinct group of strata spoken of in the preceding chapters. Anxious rather to communicate general views, than to overload the memory and distract the attention with a mention of mere names, I shall omit any particulars likely to have such an effect; and I refer the reader to those works where fossils are described in detail, if he desires to investigate for himself the nature of the evidence on which general views have been founded. In the present chapter I shall have to describe only those forms of animal life of which fossil remains have been found in the older rocks, and which appear

to have been deposited in those ancient seas where first was heard the command of the Almighty, to "bring forth abundantly the moving creature that hath life."

There will thus come under our notice, in the first place, the remains of animated beings of comparatively simple organization, chiefly the *Brachiopodous* and *Cephalopodous* Mollusca and the Crustaceans, which, with certain corals, make up more than three-fourths of the whole number of older Palæozoic species. And although amongst the remaining fourth, fragments of some species of fish have been found in Upper Silurian rocks, I shall not now allude to them; because, taken as a group, the total absence of vertebrated animals in the Lower Silurians, and their extreme rarity in the Upper, is, unquestionably, a characteristic mark of this first period, in all countries where it is represented by fossiliferous strata.*

I have already observed, as a general characteristic of the older rocks, that they contain many species of fossils having a wide horizontal range—which are found, that is, in distant parts of the earth,—and some also (usually identical with the former), whose existence was continued

* To this method of considering the fossils, it may seem an objection that those groups of animals most numerously represented will sometimes not be described in speaking of the formation in which they abound. But as I have already observed in the text, my object is to give general views, and not palæontological details; and thus, although in the Devonian system there are upwards of seven hundred known species, of which scarcely more than fifty are referred to the class of Fishes, I shall chiefly describe the generic forms of the more remarkable of these latter, and neglect, or pass rapidly over, all the Invertebrata, because the real character of the formation, so far as regards Palæontology, and that point in which it differs most from the rocks above and below it, must be sought for unquestionably in the remains of these few vertebrated animals. On the other hand, the Carboniferous system is more remarkable, on the whole, for its fossil Zoophyta, Radiata and Plants, than for its molluscous remains; notwithstanding that between eight and nine hundred species of the latter have been described from the different strata, and that they form more than two-thirds of the whole number of species known in the formation.

through a vast thickness of different strata, deposited on the same spot, and which may therefore be said to have an extensive vertical range. This peculiarity, however, being once fairly stated, and viewed in a proper light, it will be found, on more minute and accurate investigation, that it holds good only in certain individual cases; but although it is necessary to use great caution and diffidence in forming minute subdivisions of groups, still, on the whole, it is not less true in the oldest formations than in the most recent, that the species which belong to a single system, are rarely observed at great distances; although the number of those, which at first appear to be absolutely characteristic of a system of beds, gradually diminishes as the system is studied on a more extensive scale.*

I shall not dwell long on the corals and radiated animals of the older Palæozoic period. Among the genera of the former found most commonly in the Silurian rocks is the *Lithostrotion* (*Cyathophyllum* of Goldfuss), and it is also abundant in the overlying strata. The *Stromatopora concentrica* is another coral exceedingly abundant in the Silurian strata, both of Europe and America, and passes even into the Devonian series; while the *Favosites*, or *Calamopora* is distributed through an area of nearly 1400 miles from east to west, and from the strata on the shores of the Arctic ocean to those in the Gulf of Mexico, a distance of as much as 2400 miles, from north to south.

The *Catenipora escharoides* (figure, page 127) is another extremely beautiful and highly characteristic coral, from the Upper Silurian formations.

The existing species of Zoophytes to which these, which are extinct, seem most nearly allied, are those which, at the

* Geol. Trans. 2d Ser. vol. vi. p. 335.

CATENIPORA ESCHAROIDES. Lam.

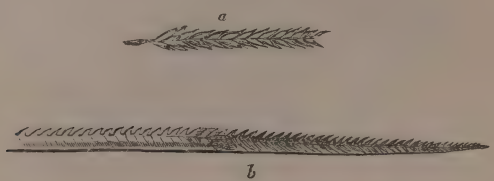
Upper Silurian.

present day, form the coral reefs and islands of the tropical oceans; and the fossils are often found occupying an important place in the strata, and forming, in actual bulk, a very considerable proportion of the whole mass of the Silurian limestones.*

Not associated with the corals, but occurring in muddy and sandy beds, even amongst the very lowest of the fossiliferous rocks, there are found, in particular localities, vast multitudes of a fossil called *Graptolites*, supposed to be the remains of Zoophytes, and related to the sea-pens of existing seas, which inhabit mud and slimy sediment in deep water. These fossils have hitherto been found abundantly only in the older formations of the Palæozoic period, and have not been described from Devonian, or newer beds

* A fossil of which (under the name *Cornulites*) a figure is given at the end of the chapter, deserves mention in this place among the organic remains of the Silurian period, although great doubt exists as to its proper position among organized beings. It appears, however, to have been the habitation of Polyps, and is apparently made up of a pyramid of broad rings, or cups, gradually increasing in size, and capping, but not covering, each other; each cup, or ring, being thinnest at that part which is enclosed by the succeeding ring, where also its diameter is least. The principal localities for these singular fossils are the Wenlock limestone, in the neighbourhood of Ledbury, (on the western flanks of the Malverns,) and the same rock near Dudley.

of the series; although it seems not unlikely that they exist even in much more recent formations.



GRAPOLITES. LINN.

a. G. foliaceus. Murch. *Caradoc Sandstone.*
b. G. ludensis. Murch. *Ludlow rock.*

Of the Crinoidal forms assumed by the Radiata in the older rocks, there are some peculiar to the Silurian period, and sufficiently remarkable; but the variety of species is not very considerable, and allied forms will be described in detail in a subsequent chapter.

Among the most interesting of the organic remains which characterise the lower Palæozoic strata, are those of Crustacean animals, almost peculiar to them, and well known under the name *Trilobites;* fossils of some species of which are found throughout the Palæozoic series, but which seem to have been chiefly developed during the earlier deposits.

Few fossils are more calculated to attract the wondering observation of the common observer than these remains of the horny cases of Crustacean animals, whose appearance differs so much from any form of animal life with which we are familiarly acquainted. The odd crescent-shaped head, with its prominent and insect-like eyes, resembling those of a dragon-fly; the strange jointed body, with its tripartite division; the absence of all limbs; and, on closer examination, the flat under surface of the body, and the peculiar margin of the horny case, are all calcu-

lated to excite the curiosity of any one who takes an interest in the works of Nature.

Trilobites are the remains of Crustacean animals allied to certain species now living, although the degree of approximation is by no means clear.* Indications of legs and feet have been supposed to be traceable in some specimens, but they have not yet been satisfactorily made out. On the other hand, this deficiency is partly made up by the perfection of the organ of sight, which is very complete; and the animal seems to have been provided with the means of defending itself, being enabled to roll itself into a ball, like some of the smaller living Crustaceans, and the common woodlouse. It is common to find vast multitudes of these fossils heaped together in the same spot; but in spite of this apparent evidence of their sessile habits, we are obliged to conclude that an animal provided with eyes, and which, from its form, appears to have been capable of crawling over, as well as attaching itself to, a flat surface, must have had to search for its food, and therefore must have possessed some powers of locomotion, however limited. Its feet were, however, in all probability, small, membranaceous, and even rudimentary; and in some species,† the full grown animals seem to have adhered together in

* The existing Crustacean which resembles most nearly the extinct Trilobite, appears to be the *Bopyrus*, a small parasitical animal attaching itself to prawns. In this creature the position of the eyes, the absence of antennæ, &c. and the indistinct articulation of the body to the head, offer such striking analogies with the Trilobites, that Mr. M'Leay has observed, "if the *Bumastus* of Murchison (a well known Silurian species, allied to the Trilobite,) had a body of thirteen equal segments, with short Crustacean feet, it would be a male Bopyrus." Other species of recent Crustaceans, allied to Bopyrus, have the property of rolling themselves up into a ball,—in this respect also resembling the Trilobites.—*Vide* Murchison's Silurian System. Observations on Trilobites by M'Leay, p. 667.

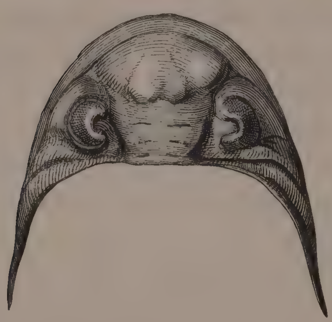
† This is the case with the common species (*Calymene blumenbachii*) figured at the end of the last chapter, p. 123.

masses, forming conglomerations of individuals which are occasionally found in the upper Silurian rocks.*

The eyes of Trilobites are often perfectly well preserved, and offer many points of interest, and also give us some idea of the condition of the early seas in which these animals lived.

The form of the eye is generally that of the frustrum of a cone, incomplete on the side which is directly opposite to the corresponding part of the other eye. In this way the exterior of each ranges round three-fourths of a circle, and is made up of a number of distinct spherical lenses, fixed in separate compartments on the surface of the cornea. The form of the cornea is such, that the animal is enabled to see distinctly in all directions horizontally.

The species of Trilobite called *Asaphus caudatus* is admirably adapted in this way for extended and perfect vision, each eye containing not less than four hundred spherical lenses. This species is found most abundantly in the upper beds of the Silurian series; and is one of those which we believe to have been among the earliest of created beings. Its structure seems to prove that during the formation of some at least of the oldest strata, the waters of the ocean could not have been in that turbid state which the rapid deposit of sandy and muddy beds would



HEAD OF ASAPHUS CAUDATUS. Brong.

* The same phenomenon is also observed with the *Asaphus buchii* in the lower Silurian rocks.

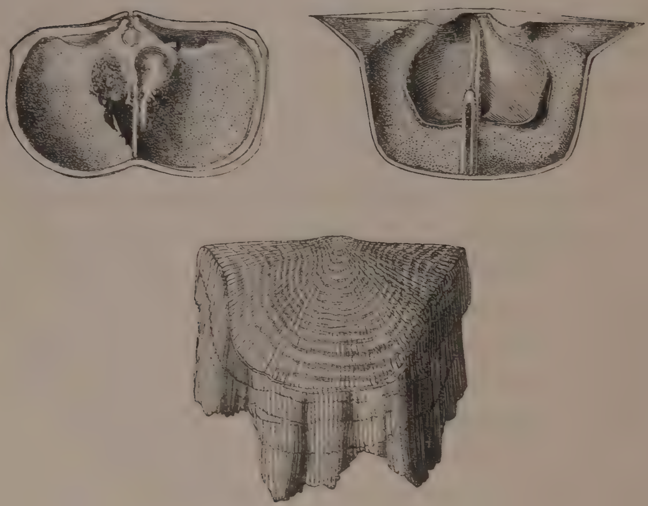
produce; because the structure of the eyes of these animals, the inhabitants of the bottom of the sea, required a fluid sufficiently pure and transparent to allow of the passage of the rays of light freely and without intermission. We may also conclude, that the atmosphere could not have differed materially from its actual condition; and that the mutual relations of light to the eye, and the eye to light, cannot have greatly changed since the period when these Crustaceans, endowed with the faculty of vision by means of contrivances similar to those now adhered to, were first placed in the primeval seas. "We find in these animals an optical instrument of most curious construction, adapted to produce vision of a particular kind, created in the fulness of perfection, and fitted for the uses and condition of the class of creatures to which this kind of eye ever has been and is still appropriate." *

Of the remains of Molluscous animals, found in the older rocks, the shells which are the most abundant, and in which there is the greatest variety of species, belong to the class Brachiopoda,†—a class represented only by a very scanty remnant in the present seas, but offering differences of structure, and doubtless corresponding differences of habit, well deserving of special notice.

The Brachiopoda were so called by Cuvier because some animals of the class are enabled to stretch out two spiral arms, placed one on each side of the mouth, and in this way to obtain food, and also assist in locomotion. They inhabit bivalve shells, but the valves are not united by a hinge as is the case with the other Mollusca, being connected together in a different way, a moveable bundle of fibres being sometimes attached to one shell and

* Buckland's Bridgewater Treatise, vol. i. p. 403.

† From two Greek words βραχίων, an arm, πόδα, feet.



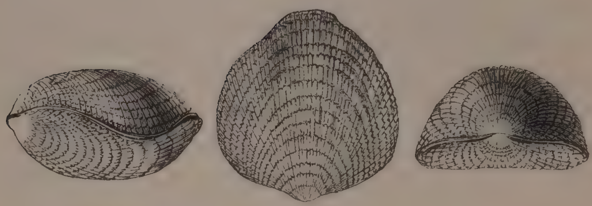
LEPTÆNA DEPRESSA. Dalm.
Upper Silurian.

passing through an aperture in the beak of the other (as in the genus *Terebratula*), while analogous contrivances are observable in other genera.

The spiral arms, above alluded to, are not always capable of being extended beyond the margin of the shell; they take their origin from the two sides of the mouth, and being covered with *cilia* (or hair-like appendages), produce currents in the water by a succession of extremely rapid vibratory movements, and they are thus enabled to draw towards the mouth whatever nutritive particles there may be in the vicinity. Some such contrivance was absolutely necessary for an animal of this kind, which, being entirely without any prehensile instruments, having no teeth, and being fixed invariably in one locality, would otherwise be totally unable to obtain nourishment.

The so-called spiral arms are not only often incapable of being protruded beyond the shell, but are also much confined in their movements within it, being connected together, throughout their whole length, by a peculiar apparatus which is attached to the internal surface of the imperforate valve of the shell. In a recent species which has been examined, this framework consists of a slender flattened calcareous loop, the extremities being fastened to the sides of the valve, and the loop considerably extended and bent back upon itself. This singular apparatus is so slender, that notwithstanding its calcareous nature it possesses a slight degree of elasticity, and yields a little to pressure, and its use seems to be connected with the opening of the shell, the convexity of the loop under ordinary circumstances pressing sufficiently upon the dorsal, or perforated valve, to separate it slightly from the opposite one, and enable the currents of water to pass round the aperture of the mouth.

The vast number of extinct species of Brachiopoda in the older rocks, (as many as six hundred have been already determined,) renders it necessary to introduce some method of classification in describing them, and that which, on the whole, seems the best, is one recommended by M. Von Buch, and other naturalists who have carefully studied this department of Palæontology. According to this method the nature of the attachment of the valves to one another is taken as the groundwork of classification; and the whole number of species is thus collected into five distinct groups, of which three are represented in the rocks of the Palæozoic period. These three form the first of two principal subdivisions of the class, distinguished by the nature of the attachment of the shell to extraneous bodies, which is from the margin and not from the lower valve.



ATRYPA AFFINIS.* Sow.
Upper Silurian.

The further subdivisions into smaller groups and genera are not, however, yet satisfactorily made out, nor do I intend to enter into any speculations on the subject in the rapid sketch I am now giving. It will be enough to mention, that those genera which have received the names *Leptæna*, *Orthis*, *Delthyris*, *Atrypa*, and *Pentamerus*, are extensively developed in the older Palæozoic rocks, while *Strigocephalus* and *Calceola* are more common in the middle, and *Spirifer* and *Productus* in the newer rocks of the series. Throughout the whole, certain species of *Terebratula* are found, and this remarkable genus, which still in the existing seas possesses some representatives, appears to have been created among the very first of the inhabitants of the ocean, and to have retained its place longer than any other.

With regard to the Brachiopoda of the older Palæozoic period, figures of some of the characteristic Silurian species will be found above, and in pp. 110, 132; but for any detailed account of them I must refer to those works in which the minutiæ of natural history are described.† But the genus Pentamerus, (see page 110,) is too re-

* Terebratula reticularis. Bronn. Let. Geog. pl. ii. fig. 10.

† Murchison's Silurian System; Sowerby's Mineral Conchology; Phillips' Palæozoic Fossils; Transactions of the Geological Society, 2d Ser. vol. vi.; Goldfuss' Petrifacta Germaniæ, &c.

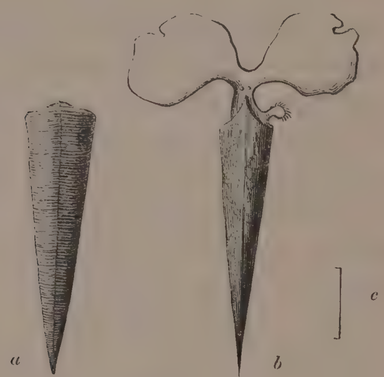
markable to be passed by without notice. In this genus the lesser valve is divided internally by two parallel walls or septa running length-wise along the shell, and close together; and the other valve has also a wall, which is forked towards the beak of the shell, the septa in each case appearing to have been composed originally of soft fibres, which meet in the middle, so that each is readily divided into two parts. Owing to this singular structure, and to the fact that the shell is usually replaced, and its interior filled by crystallized carbonate of lime, the fossil splits easily into two parts, one containing two, and the other three, of the chambers formed by the septa.

The septa seem to have represented the calcareous loops in the recent Terebratula, and the helpless condition of the animal is clearly indicated by such a contrivance.

The Univalve shells of the older Palæozoic period were not less remarkable in form, and scarcely less widely extended or abundant, than the bivalves or the crustaceans. The greater number of those whose remains are preserved belong, indeed, to an order little developed now in comparison with the earlier periods; and the various species are interesting, as introducing to our notice the highest and most complicated forms of organization among the Invertebrata.

There are several genera of Gasteropodous Molluscs, whose remains are more or less characteristic of Silurian and sub-silurian strata; but of these it is unnecessary here to give any detailed account. Besides these, there are also found, both in the Ludlow shale and in some other Silurian rocks, small and fragile shells, which were, till lately, thought to represent a peculiar form of Orthoceratite, but in which the absence of chambers seemed to be not merely an accident. Geologists are indebted to

Prof. E. Forbes for suggesting the identity of these shells with those of a genus of Pteropoda, common in the Mediterranean, and named by M. Sander Rang *Creseis*. I have figured one of two species of this genus obtained by myself from the Lower Ludlow shale at Downton, near Leintwardine, in Herefordshire, and have named it *C. Forbesii.*



CRESEIS. Rang.

a. C. Forbesii. Nob. *L. Ludlow.* *b.* C. spinigera. *Recent.*
c. Natural size of do.

Creseis Forbesii.—Shell, smooth and very thin; shape, conical, diminishing rapidly to the apex; finely marked with rather distant transverse striæ and with a deep longitudinal depression, but margin of aperture apparently not prolonged superiorly. One specimen in my possession measures two inches in length.*

The Pteropoda are small free-swimming mollusca, provided with two wing-like muscular expansions attached to the sides of the neck, and some animals of the class are partly enclosed in a shell which is light, delicate,

* I have been enabled by the kindness of Professor Forbes to accompany this engraving of the first described fossil *Creseis*, by a figure of the recent species most nearly allied (*C. spinigera*). The organ projecting from one side and fringed with vibratile cilia is the respiratory organ.

and semi-transparent. In Cleodora, to which Creseis is nearly allied, the shell is made up of two plates or valves united together along the sides, the opening being large and without lateral appendices. It is possible that a more minute examination of better specimens than are yet known may separate the extinct species from the recent genus, from which it appears, at present, to differ chiefly in point of dimensions, but there seems every probability that the fossil represents a true Pteropod.*

We have found the Brachiopodous Molluscs distinguished from the other inhabitants of bivalve shells by their apparent helplessness, and the complicated contrivances by which they were enabled to obtain their food. The Cephalopoda, on the other hand, which are also highly characteristic of the Palæozoic period, are, as a class, remarkable for being the most indiscriminate devourers of all the inhabitants of the sea less powerful than themselves; and they are unrivalled for the perfect freedom of their movements and the admirable destructive organs with which they are armed. The brachiopoda may perhaps have been the scavengers of the ancient seas, living upon such fragments of dead animal matter as found their way to the great depths;† but the cephalopoda existed and were abundant at a time when the still more voracious fish had not been introduced, and they acted as the representatives of the more highly organized carnivora, sweeping away the redundant life of which nature is so prodigal, and keeping within bounds the excessive increase of marine animals.

* At least six species of another genus of Pteropoda have also been determined from Silurian formations. This genus is called *Conularia*, and is spread over various parts of Europe and North America, and is also found in South Africa.—Geol. Trans. 2d Ser. vol. vi. p. 325.

† The recent Terebratula is remarkable for the great depths from which it has been obtained, having been found living at 90 fathoms.

The most powerful and the largest of those species of Cephalopoda which still inhabit the seas are, for the most part, unprovided with any internal skeleton or external shell, and this may have been the case always, and the most highly organized of the tribe may thus have escaped notice; but the remains that occur of the singular shells and skeletons possessed by many extinct species are quite sufficient of themselves to prove the vast extent to which animals of the order Cephalopoda were in former times expanded. They are found abundantly distributed in every fossiliferous rock, from the oldest Silurian to the chalk, and a curious and interesting change was gradually taking place in the form of their habitation, although one genus is retained throughout, being found in every formation and existing still in the southern seas.

This genus is the *Nautilus*, and it becomes a key by means of which we are enabled to understand the structure of a number of extinct genera, and explain differences of form and peculiarities in the shell which otherwise must have been extremely puzzling. The Palæontologist is indebted to Professor Owen for an account of the anatomy of the recent nautilus, as well as the recent terebratula; and the extensive and successful labours of that admirable naturalist in the application of Comparative Anatomy to Palæontology every Geologist, and, indeed, every one who takes an interest in the natural sciences, must be willing and anxious to acknowledge. As an account of the peculiarities of the structure and habits of existing Cephalopoda is necessary, in order that the reader may understand those of the extinct but allied species, I shall precede my description of the latter by some account of their singular living analogues.

A cephalopod is an animal whose body is a closed bag,

containing a heart, a stomach, and the other organs included in the great cavities of the bodies of vertebrata, and furnished with a head and prominent eyes. Upon the head are supported numerous complex organs of locomotion, which not only answer the purpose of feet, but are also powerful instruments of prehension, while in the centre of the locomotive apparatus is a pair of strong and sharp horny mandibles, not unlike the beak of a parrot, and sometimes thickened by a dense calcareous substance. These jaws are embedded in a powerful mass of muscles, whereby they can be opened or closed with great force, and also be protruded when in use. The prehensile arms, feet, or tentaculæ (for whichever they may be called they answer the purposes of all those organs), are of the most elaborate and wonderful structure, and in most of the species best known their number is limited to eight or ten, although in the nautilus they are much more numerous. In the free swimming species every one of these is provided with a double row of suckers, more perfect and efficacious than any cupping-glass, by means of which the animal can take firm hold of its prey, and conduct its victim to the jaws protruded to receive it. In the nautilus, however, there are not less than forty arms, not provided with suckers, but each being traversed by a canal, in which is lodged a tentacle possessing a considerable projectile and retractile power, and receiving large nerves.

The nautilus, also, not being provided with a powerful swimming apparatus, nor possessing, like the cuttle-fish, a bag of inky fluid to discolour the water, and avert danger when it is attacked, has another contrivance, which it shares with a large proportion of the extinct species of Cephalopoda, and by means of which, apparently, the instinctive act of shrinking at the approach of danger,

is rendered available as a means of escape from its enemies.

Like many other molluscs, the nautilus inhabits a shell; but, unlike most of those animals, it does not merely provide for itself a coating of carbonate of lime, fitted more or less accurately to the shape of its body, but a perfect machine, composed of a large number of empty chambers, successively built off as the creature has enlarged in size and increased the dimensions of the outer one. Through all of these an elastic tube passes, terminating in the cavity of the heart, which cavity, under ordinary circumstances, is filled with a certain quantity of dense fluid. The animal, living in the outer chamber, is in free communication with the surrounding medium.

The shell of the pearly nautilus must be familiar to every one; but the object of the singular accumulation of a number of small compartments, or chambers,—separated from one another by strong walls (usually called *septa*), which have a tube passing through, but not communicating with them,—is not so obvious; nor has it been understood till lately. The explanation, however, is simple and satisfactory; and little doubt can exist that the same explanation is perfectly applicable in the case of many extinct species, as well as in the living nautilus.

The peculiar construction of the chambers is evidently intended to render the whole mass of the animal and its shell, lighter than water; and, just as in a life-boat, a number of copper tubes filled with air renders the boat and its contents buoyant, these chambers are so contrived, that the weight of water displaced shall equal the weight of the animal of the nautilus, together with that of the habitation; the whole just floating, and having no ten-

dency to sink, when the tube, as well as the chambers, are filled with air of the usual density, and the head and arms are expanded.

Now, if the animal thus floating is suddenly alarmed, or desires to sink, the simple retraction of the arms and the head into the shell will produce a certain amount of pressure on the fluid in the pericardium, and force it into the tube, or *siphuncle;* the air in which will become compressed, and the specific gravity of the whole mass be increased. The animal, with its shell, will immediately sink, with a rapidity proportionate to the energy of the force exerted. When at the bottom of the water, the mere protrusion of the arms and head will have the effect of relieving the pressure, unless the animal choose to continue it by a voluntary muscular effort; and, when the pressure is taken off, and the whole mass thus lightened, it will rise to the surface like a balloon.*

The cephalopodous animals, whose remains are most abundantly distributed in the older Palæozoic rocks, had their numerous chambers not twisted round a central axis, as in the nautilus, but placed one over another in a position more or less nearly approaching the vertical; and not less than eighty species of these have been determined. The straight form of the shell is best known by the generic name *Orthoceratite*, but the names *Lituite*, *Phragmoceratite*, *Cyrthoceratite*, and *Gomphoceras* are also

* Professor Owen, however, is of opinion, that the power which the animal of the nautilus enjoys of altering its specific gravity, is rather analogous to that possessed by the freshwater testaceous gasteropoda, and depends chiefly upon changes in the extent of surface which the soft parts expose to the water, according as they are expanded to the utmost and spread abroad beyond the aperture of the shell, or are contracted into a dense mass within its cavity.—Lectures on the Invertebrata, p. 330.

GOMPHOCERAS PYRIFORME, SIL. SYST.
Upper Silurian.

applied to distinguish differences of form, chiefly marked by the axis of the chambers being more or less curved; the chambers of none of them, however, being twisted into a complete spiral.

The method of arrangement of the chambers, in these numerous species, and their number, (in some instances amounting to not less than seventy,) seems to prove, beyond a doubt, that the animal provided with this unwieldy column work of stony plates did not enclose them within the body: and we may safely conclude that, in this respect, the analogies were rather with the Nautilus than with any of the naked Cephalopoda.

In the open seas, however, in which the earliest strata were being deposited, we may picture to ourselves these large cephalopodous molluscs reigning paramount,—the tyrants of creation; enabled, by their rapidity of movement, to chase their prey at the surface; by their curious hydraulic contrivance, to pursue it to the depths

of the ocean; and, by their numerous arms and great strength, to conquer and bring it within the grasp of their powerful jaws. The recent animals of this class are so fierce that, even in our own seas, where they occupy a place comparatively unimportant, they rank amongst the most destructive species, in proportion to their dimensions; for, "if they once touch their prey, it is enough: neither swiftness nor strength can avail; the shell of the lobster and crab is a vain protection; and even animals many times their size have been soon disabled in their powerful and pertinacious grasp."*

Such, then, are the animals whose remains are found fossil in the rocks of the older Palæozoic period; and such are the results of what have been sometimes, but irreverently, called the first efforts of creative power.

We recognize, however, in these first efforts, none of the imperfections and crude attempts which belong to experiments, and which, by a succession of failures, produce at length a satisfactory result; nor, on the other hand, do we find the same contrivance, or a contrivance precisely analogous, indicating an arbitrary and necessary succession, without reference to any adaptation to circumstances. We find, by examining the fossils, that large groups of animals existed, perfect in their kind, and faintly shadowing forth, by their structure and habits, the future history of life in the world. The same laws which now govern and regulate the progress and the destruction of species appear also then to have been in action, but in a modified form: animals of the highest organization, in their respective classes, then, as now, existed, and were provided with organs of sensation constructed on the same mechanical principles, and adapted to the same atmo-

* Rymer Jones' Animal Kingdom, p. 432.

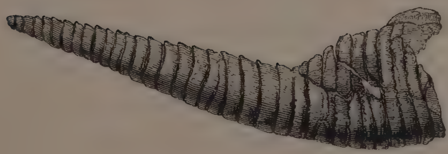
spheric conditions, as our own; for there were at least some species created sensible to the stimulus of light, and enabled to rejoice in the exercise of powers which have been handed down, in the same form, to their latest successors.

And although we are doubtless acquainted with the nature of a large number of the inhabitants of the sea at the early period we are considering, it must not be forgotten that every day is adding to our store of information on this subject, and that it is always dangerous to draw conclusions from negative facts. Of the existence of land or freshwater animals of this period we are at present totally ignorant, but it ought not, for that reason, to be assumed that the whole earth was therefore covered with sea, and entirely peopled by marine animals. We may yet hope to discover some ancient shore, or the bed of a lake, in which the remains of land or freshwater animals have been deposited and preserved, for such discoveries have already been made in several strata of the secondary period, and even in the carboniferous rocks; although no one has hitherto been so fortunate in Silurian or sub-silurian formations.

Before concluding, there is one important general observation which still remains to be offered; namely, that in the long series of ages that must have elapsed during the accumulation of the thousands of feet of fossiliferous strata, which together make up the system of the older Palæozoic period, the changes which took place in the conditions of life were gradual, but, when examined in the same locality, perfectly regular and appreciable. Upwards of eight hundred extinct species of animals have been described as belonging to the earliest, or Protozoic and Silurian, period, and of these only about one hundred are found also in the overlying Devonian series, while but fifteen are

common to the whole Palæozoic period, and not one extends beyond it.* The subdivisions of the Silurian formations in England are clearly marked by differences of organic remains, and although it cannot be denied that these differences may be partly owing to changes in the mineral character of the beds, still such slight differences as exist between the limestones and shales cannot at all account for the absence of whole groups in the one which are common to the other, and still less for the extreme abundance of particular species in some rocks, and their rarity, or total absence, in similar rocks of newer origin.

* M. de Verneuil and Count D'Archiac. Transactions of Geol. Soc. 2d Series, vol. vi. p. 308.



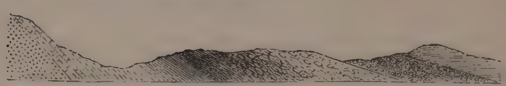
CORNULITES SERPULARIUS. Schlot.

Upper Silurian.

THE MIDDLE PALÆOZOIC PERIOD.

CHAPTER VII.

THE OLD RED SANDSTONE.



SECTION ACROSS THE OLD RED SANDSTONE OF HEREFORDSHIRE.*

The formation which has long been known under the name of "Old Red Sandstone," but which till very lately has been described as a lower and arenaceous member of the carboniferous series, is now ascertained to represent an extensive fossiliferous group of strata intermediate, in all respects, between the Silurian and the carboniferous systems; and, although totally distinct in mineral character, is contemporaneous with various formations occurring in other parts of England and on the continent of Europe. It is in the Welsh counties of Brecknockshire and Pembrokeshire, and in Herefordshire, Worcestershire, and Shropshire

* 3. Old red conglomerate.
2. Cornstone and marl.
1. Tilestone.

It must be understood, however, that the names here applied to the different groups, rather indicate the character of the predominant strata in each, than apply to the different subdivisions exclusively, as in every part of the series, for instance, fissile beds may be found which can be used for tiles, and in the group called "Tilestones" it is not at all rare to find beds of coarse conglomerate.

in England, as well as along the eastern and western coasts of Scotland, that the peculiar series of beds called more especially the "Old red sandstone" is developed, and this having been longer known than the contemporaneous beds in Devonshire and Cornwall will first demand our attention in speaking of the rocks of the middle Palæozoic period.

The Old red sandstone of England has been subdivided into three groups represented in the diagram page 146, and it may be considered to lie in a vast depression, or trough, bounded by the rocks of the Silurian system both on its eastern and western flanks. Examples of the actual passage of the upper Ludlow shales into the tilestone may be seen on the edges of the basin, and also in some valleys of elevation on the eastern side. In Wales the whole series is, for the most part, regularly bedded and of great thickness.

The *tilestone* (1) forms, on the whole, the smallest member of the old red formation, but possesses very marked characters both in structure and fossil contents. It is clearly defined, occupying the loftiest parts of the escarpments of a wild mountain range, attaining an elevation of fifteen to sixteen hundred feet, and running from Llangadock, in Caermarthenshire, in a north-easterly direction through Brecknockshire, to Builth on the borders of Radnorshire.

Throughout this extensive range of highly inclined beds the tilestones are extensively quarried, and consist of hard finely-laminated micaceous and quartzose sandstones of a greenish colour, usually associated with reddish-coloured shales, which decompose into a red soil, therein generally distinguished from the upper Silurian rocks, which decompose into a grey soil. In this part of the system organic remains are abundant in particular localities, and often indicate the lines of deposit, when transverse cleavage, and the

faces of joints, would otherwise render the bedding difficult to be distinguished.

The upper beds of the tilestone are overlaid by the great central mass of the Old red sandstone system, as developed in England and Wales. This mass consists of a number of argillaceous marly beds, sometimes alternating with sandstone and sometimes with impure limestone, affording, by decomposition, the soil of the richest tracts of Herefordshire, Monmouthshire, &c. and locally called *cornstone* (2).

The lower part of the cornstone contains very often flaggy beds, some of which are extensively quarried near Downton Hall, the stone being of a greenish colour, and highly micaceous, and usually more or less intermixed with party-coloured marls, or soft argillaceous sandstones, not so compact as the rock which encloses them. The surface of the sandstone is frequently worn into irregular holes and patches.

But the subdivisions of the sandstones are too entirely local to allow of any lithological character being given, which can apply to more than a very limited district. Generally speaking, the impure concretionary limestone, which is more especially denominated cornstone, appears at intervals, in irregular lenticular masses throughout the district, contracting and expanding in the most capricious manner; sometimes replaced by finer and more crystalline limestone, and sometimes alternating with hard flaggy sandstones. Nearly the whole of the central and northern parts of Herefordshire, and the contiguous parts of Shropshire and Worcestershire, are occupied by this formation; and its vast thickness is remarkably well displayed in the hills crossed by the new road from Leominster to Hereford. In the northern portion of the range, and near the mouth of the Towey, in Caermarthenshire, the limestones are

most fully developed, becoming much thicker, and also more crystalline, than in other parts.

Whenever the order of superposition is not apparent (a case by no means unusual) the fragments of fossil fishes, which are distributed abundantly throughout the cornstone series, will be sufficient to distinguish between these rocks and others of newer date, which much resemble them; and this is the more easily done, as the fragments of fish assume very peculiar forms, and often, by their brilliant lustre, attract the eye, and enable the Geologist immediately to identify the stratum.

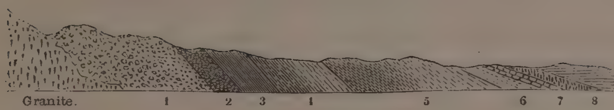
The uppermost strata of the Old red sandstone in England, consist sometimes of conglomerate, but more frequently of beds of sandstone, hard and finely grained, and alternating with a few imperfectly exhibited mottled marls. The lower portion capping the escarpment of the cornstone in Herefordshire, furnishes thick beds of valuable building material, and is occasionally quarried for tiles. The upper beds are, for the most part, less compact, and commencing as a fine conglomerate they afterwards become coarser, and alternate with bands of red and green argillaceous marl. Fine examples of the conglomerate beds (attaining near Abergavenny a thickness of 200 feet) may be seen on the banks of the Wye, between Ross and Monmouth, and again on the right bank of that beautiful river, to the north of Tintern abbey.

The loftiest points occupied by the Old red sandstone of England, are the Vans of Caermarthen and Brecon, the former 2590, and the latter 2500 feet above the level of the sea. These hills are made up of a conglomerate, composed of white quartz pebbles, embedded in a red matrix; and it is this *quartzose conglomerate* (3) which gives its name to the uppermost group of the formation.

On the whole, therefore, it appears,—first, that the Old red sandstone of central England and Wales reposes conformably upon the grey coloured rocks of the upper Silurian system, into which it passes by insensible gradations; secondly, that it consists of various strata of tilestone, limestone, marl, and sandstone, alternating with great thicknesses of conglomerate, which often pass upwards into overlying sandstones; and, thirdly, that it is expanded over a considerable portion of our island, rising into lofty mountains, spread over extensive plains, and developed to an enormous thickness. It is also fossiliferous, and contains many characteristic fossils of a remarkable kind, well deserving special consideration, even if the formation were to be considered without reference to the contemporaneous series in the south-west of England, and other parts of Europe.

In North Wales, although the Old red sandstone retains its general character, we find it diminishing in thickness and importance. It again increases, however, as we advance still further northwards into Westmoreland and Cumberland, where it appears as an irregular conglomerate. In this part of England its largest development is near the foot of Ullswater, and it rises into a succession of round topped hills several hundred feet high, the beds being of great thickness. No true passage is there discernible into the overlying limestones; but, on the other hand, the sequence is so perfect from the Ludlow rock into the tilestone, that a line of separation cannot be drawn.*

* This fact was first stated by Professor Sedgwick, and the tilestone—the lowest member of the Old red sandstone series—is now considered to belong rather to the upper part of the Silurian system than the Old red sandstone. The evidence of fossils is certainly sufficient to justify this change of position, but in the present state of our knowledge of the true limits of the three groups of Palæozoic rocks, it is more convenient to adhere to the original subdivisions, and describe the tilestone as the oldest member of the middle Palæozoic period.



SECTION ACROSS THE OLD RED SANDSTONE OF SCOTLAND.*

We have now to examine the superposition of the same rocks as they appear on the northern coasts of Scotland, where their order was first accurately made out by Professor Sedgwick and Mr. Murchison. The paper read by these gentlemen before the Geological Society in 1828, and afterwards published (*Geol. Trans.* 2d Ser. vol. iii. p. 125), and the papers of Dr. Malcolmson, (*Proceedings Geol. Soc.*, vol. ii. p. 168; iii. p. 141,) may be safely referred to for detailed sections and minute information on the Geology of Caithness and the shores of the Murray Firth, while the work of Dr. M'Culloch, on the Western Islands of Scotland, abounds, also, with valuable information concerning the deposits of the north-western coasts.†

The granite and gneiss, which are largely developed in Scotland, and form the mineral axis of that country, appear

* Upper.	8. Quartzose yellow sandstone.
	7. Impure limestone.
	6. Gritty red sandstone.
Middle.	5. Grey fissile sandstone.
Lower.	4. Red and variegated sandstones.
	3. Bituminous schists.
	2. Coarse gritty sandstone.
	1. Great Conglomerate.

† I must not omit to mention here, among the writers on Scottish Geology, Mr. Hugh Miller, whose admirable work, entitled "Walks in the Old Red Sandstone of Scotland," ought to be in the hands of every one, Geologist or not, who can appreciate the lively and natural descriptions of a self-taught genius.

to have been covered, at a very early period of the earth's history, by thick and rapidly formed beds of coarse conglomerate, probably the *débris* of the older rocks, scattered and destroyed during disturbances, which must have greatly affected, if they did not actually produce the physical features of the country. These conglomerates are now found extended in an almost unbroken line for 120 miles from Dumbarton to Stonehaven, attaining a thickness of many thousand feet, forming the flanks of the Grampians, and covering almost the whole county of Caithness. The same deposit may also be traced from Brora Loch southwards to Inverness, and from thence far into Banffshire, and through the chain of Lochs, nearly to the Isle of Mull; while at intervals along the coast smaller portions, which have apparently escaped the denuding process, still remain to attest the ancient extent of the formation. The same beds are again found along the whole north-western coast, from Cape Wrath to the Isle of Skye, while the Isle of Arran, in the south, and the Orkney Islands in the north, present similar appearances, and the rocks are characterised by identical species of organic remains.

The localities, however, which are most interesting as containing the types of the formation, and which exhibit a complete series in its greatest extent, are (1) the flanks of the Grampians and the county of Forfarshire, in the south of Scotland; (2) Caithness and the Orkney Islands, in the north; and (3) the western coast of Sutherland, the coast of Rosshire, and the Isle of Skye.

The base of the whole system is represented by Mr. Miller as consisting of an extensive and thick conglomerate (diagram, p. 151), rising into a lofty mountain-chain in the county of Caithness, and attaining an elevation of

3,500 feet in the hill called Morrheim, which is entirely composed of the lowest beds of the series.

Resting on this conglomerate, and also exhibited in that part of the group which extends from Cromarty to Banffshire, there occurs a coarse sandstone, of a red and yellowish colour, occasionally containing pebbles, and alternating with green and red marls; and the difference between this and the underlying rock is chiefly mechanical, those pebbles and stones which were not included in the earlier formed conglomerate having been broken and pounded in the course of time, and at length deposited as sand.

Over these arenaceous beds there is an enormous thickness of strata, composed of slightly micaceous, calcareous, and bituminous schists, which form excellent paving stones, and are extensively worked for that purpose. The various beds of this schist are loaded with fossil fish, and contain also obscure vegetable impressions; and the same rock is developed under a slightly different form in the Cromarty district, and in the Orkney islands, the fossils in all these places being alike and almost equally abundant. The upper beds of the series consist of red mouldering sandstones and variegated marls, which are exhibited in the lofty precipice of Dunnet Head, the most northerly part of Scotland, and also in the red and mottled marls which form the uppermost beds in the group of sandstone on the south border of the Grampians. These beds also contain extinct species of fish of large size, fragments of teeth having been found near Elgin which measure two inches in length, and more than an inch in diameter at the base.

The middle group of the Old red sandstone of Scotland, corresponding to the *cornstone* of England, is developed in the county of Forfarshire, in Moray, and in the

grey sandstone of Balruddery, where the lower beds are absent. It is represented as consisting, for the most part, of rocks of a bluish grey colour, sometimes, as at Balruddery, resembling the Silurian mudstones, at others forming a hard fissile flagstone exported as a paving stone, and occasionally appearing in beds of friable stratified clay, easily washed away by the sea.

The colour, however, throughout is grey, and in this respect differs essentially from the English contemporaneous beds, which consist chiefly of red and green marls.

The upper part of the formation is divided by Mr. Miller into three parts, but there is some doubt as to the order in which these occur. The beds consist of red conglomerate and variegated sandstone (5), alternating with limestones (6), and occasionally surmounted by thick masses of yellow quartzose sandstone (7).* This upper part of the formation is largely developed in some localities, and is spread over extensive areas, being also richly fossiliferous. The limestone band is barren of fossils, and is of somewhat singular composition, yielding unequally to the weather, and exhibiting a brecciated aspect. It contains masses of chert exceedingly hard, and these, from the manner in which they are incorporated with the rock, appear to have been of contemporaneous origin. The bed is several yards in thickness, and is very persistent, being found both in Moray and in Fife, localities a hundred and twenty miles apart.

The upper quartzose sandstone rarely passes by regular gradation into the overlying carboniferous deposits in the northern part of Great Britain. It differs, too, entirely from the upper beds of Herefordshire in the condition of the deposit, the latter being unfossiliferous, while the former

* See diagram, p. 151.

abound with organic remains; but, on the whole, the two appear to be nearly contemporaneous, and to represent differences that existed at the period of deposition, the sea in the one case being tranquil and the deposit slow, while, in the other, the coarser conglomerate may be due to more rapid deposit in a troubled ocean.

The subjoined vignette represents a very interesting locality on the coast of Argyleshire, where the Old red sandstone conglomerate, is based upon the clay slate, and forms the last of those numerous patches which are met with in the west of Scotland, north of the great chain of the Grampians.

VIEW OF OBAN.

CHAPTER VIII.

THE DEVONIAN SYSTEM.

SECTION ACROSS DEVONSHIRE.*

The establishment of the Devonian system as a group of stratified fossiliferous deposits, occupying a considerable tract in the south-west of England, and greatly developed on the continent of Europe—the whole being contemporaneous with and representing the Old red sandstone, and, therefore, intermediate between the Silurian strata and the carboniferous series,—is one of the most interesting events in the modern history of Geology, and calls for some especial notice in this account of stratified rocks.

So lately as the year 1836, the true geological position of a group of strata occurring in Devonshire and Cornwall, and of other groups on the continent since proved to be contemporaneous, was completely misunderstood; and owing to a peculiar appearance which they presented, and the condition of the few fossils at that time obtained from them, they were imagined to be of much older date than they really are, and were referred to the heterogeneous group of *grauwacké* rocks. In the course of the year abovementioned, however, Professor Sedgwick and Mr. Murchison examined carefully the carbonaceous group of North

* 1. Devonian beds. 2. Culm measures.

Devon, now called "the culm measures" (see diagram), and came to the conclusion, that the whole group so designated should be withdrawn from the grauwacké system, and classed amongst the carboniferous rocks; thus assigning a comparatively recent date to a district occupying nearly one-third part of the surface of Devonshire, and offering a point of departure from which the true age of the older rocks might be determined. During the autumn of the same year Professor Sedgwick recorded his opinion, that the fossiliferous slates on both sides of Cornwall were coeval and continuous with the calcareous rocks and slates of North and South Devon.

Before that time the fossils of the Silurian system of Mr. Murchison had undergone careful examination by Mr. Lonsdale,* who had familiarized himself more especially with the corals of the older rocks and of the carboniferous system, and in whose hands were placed many of the organic remains, obtained by Professor Sedgwick and Mr. Murchison in the course of their investigations in the Plymouth beds of the so-called Devonian grauwacké.

While examining these, and comparing them with others already familiar to him, Mr. Lonsdale's attention was arrested by the fact that many species of corals from South Devon resembled, or were absolutely identical with, Silurian fossils, and that many others corresponded with those of the carboniferous system, the rest not being referrible to any known species, but the whole, as a group, exhibiting a peculiar and intermediate palæontological character. Professor Sedgwick and Mr. Murchison, aware of the great difficulty of the sections, and conscious of these resemblances, (which had also been suggested by Professor

* The late Curator of the Geological Society.

Phillips and Mr. Sowerby, though not on such good evidence,) ventured at length to generalise by comparing North and South Devon with Cornwall, and asserted, that the series in each belonged to the same period. They also suggested, that the true place of this series must be between the carboniferous and the Silurian systems, and that the Devonian system should take a distinct place in the list of stratified formations.*

To do justice, however, to the boldness and decision exhibited in arriving at this conclusion, it ought to be remembered, that up to the time when these fossils were examined by Mr. Lonsdale, the most that had been done by others in the way of identification was the connecting the *killas* of Cornwall (supposed to belong to the earliest period) with the lower beds of North Devon. In this way the phenomena were still further complicated, because the culm beds of Devonshire had been by this time ascertained to exist in a trough, and to be newer than the other strata found in the district, from which they were distinguished both by physical structure and also by organic remains.

Below the culm, several fossiliferous beds had indeed been made out, and the actual order of superposition was determined with some approach to certainty: but the whole series was placed absolutely below the Silurian system, and this was done partly from lithological peculiarities —the highest group appearing to resemble the Caradoc sandstone, — and partly also from the mineral structure

* The publication of the Geological Survey of Cornwall, Devon, and West Somerset, by Sir H. T. De La Beche, has added very considerably to the knowledge before possessed by Geologists of the mineral peculiarities of the Devonian rocks. Much valuable detail is given in this volume, and it has been succeeded by an account of the Palæozoic fossils of the district, prepared by Prof. Phillips, also under the superintendance of the Ordnance survey.

and slaty cleavage of many parts of the lower groups. It is true that several of the south Devon fossils were known to conform to carboniferous types; but, on the other hand, no one was able to define the descending range of such organic forms; especially as it was asserted, that they re-appeared in the south of Ireland in beds older than the Old red sandstone.

In the summer of 1838, Professor Sedgwick again visited and re-examined a part of the district under dispute, and then found that the calcareous slates of South Petherwyn on the south, and of Barnstaple on the north, emerged with perfect symmetry on the opposite sides of the culmiferous basin, and that, however dissimilar in mineral character they might be, the slates in question must be looked on as immediately antecedent to the culm beds, and therefore as equivalent to the upper beds of the Old red sandstone. This identification being admitted, it became impossible to resist the conclusion, that all the fossiliferous slates of South Devon and Cornwall, as well as the calcareous rocks of North Devon, are of the same age as the Old red sand-stone.

In this condition of the question a much larger series of fossils than before was carefully examined, and in the spring of 1839 the new classification of the stratified rocks of Devon and Cornwall was proposed, and, after some consideration, universally accepted, as a real and sufficient explanation of the Geological phenomena of that part of our island.

The history of this change—perhaps one of the greatest revolutions of Geology in modern times—is marked therefore by the following successive steps, and a statement of them in a formal way is useful, as illustrating the process by which important modifications of views have been introduced into Geology.

In the first place, and before it was possible to attempt any classification, correct sections of the mineral masses were prepared, and a point of departure obtained by the identification of the carbonaceous beds and the culm limestone with similar beds in other districts, where the sequence was made out more directly, and the connection with previously known strata was well established.

Secondly, the relative position and the succession of the various calcareous and fossiliferous groups was established by actual sections in different parts of the district.

Thirdly, the evidence arising from the examination and comparison of fossils, was brought to bear upon the discussion, and the suggestions offered in consequence of such investigation induced a further and more minute examination of the actual order of superposition of the beds, and the nature of their passage into the known overlying group; and at length, when, by two independent methods, the same result had been attained, it was finally understood, that, in spite of a total difference in mineral character and peculiarities of structure which appeared to connect it with the oldest formations, the whole series really belonged to a much newer period than had been supposed, and the fossils being intermediate in character between those of the Silurian and the carboniferous systems, it was clear that the period was that of the Old red sandstone.

And lastly, the Old red sandstone having been exhibited in so different a form from that in which it was hitherto known, and on so large a scale, the newly identified rocks being characterised also by peculiar organic remains, it remained only to seek for their true equivalents in other parts of Europe, and endeavour to identify the ancient fossiliferous rocks of the grauwacké system, with some one or other of the formations newly determined in England.

The consideration of the foreign types made out by means of the discovery of the true age of the Devonian system in our own country, will occupy us in the ensuing chapter.

The lowest beds of the Devonian, or middle Palæozoic, period, in the south-west of England, are to be sought for among the calcareous slates of Cornwall and South Devon. These calcareous slates are occasionally fossiliferous, and are based upon an impure limestone, which thins out towards the north end of Gerran's Bay, where all traces of organic remains are lost. The Plymouth limestone in the south, and a group of coarse arenaceous beds in the north of Devon, together with the general series of Cornish rocks, are all included among these calcareous slates. Throughout the whole series fossils occur, but they are very unequally distributed, being locally abundant, although, owing to the metamorphic character of many of the beds, they are sometimes much altered, and frequently obliterated.

The lower group, just described, is covered up in South Devon by an extensive series of coarse red flag-stones and slates, which are thought to correspond with similar beds in Exmoor forest, and are overlaid by other slates without limestone, and rarely containing organic remains. On the two sides of the great trough of the culm measures there is, however, a considerable difference of mineral structure, the beds in North Devon being on the whole coarser than the others, and irregularly calcareous, while the South Devon and Cornish series contain numerous fossiliferous calcareous bands.

The development of the Old red sandstone and the contemporaneous beds in Ireland, is peculiarly interesting, as completing within the circuit of our own islands the whole of the chain of evidence necessary to establish the true place of the Devonian grauwacké. In the south of Ireland, as in

the south of Scotland, the sequence is perfect from the upper beds of the Silurian system into the lower beds of an extensive series of coarse conglomerates, which there represent the Old red sandstone, and these pass upwards through the numerous gradations of the same formation in Herefordshire, until they are at length replaced by roofing slates, resembling those at the base of the culm measures of Devonshire, and are finally succeeded by similar strata,—the great coal fields of the south of Ireland assuming the exact character of the Devonian culm. It is clear that the formations in Devonshire, containing fossils which are intermediate in character between the carboniferous and Silurian systems, must themselves occupy an intermediate position, and must therefore be on the parallel of some part of the Old red sandstone, which is thus shown to fill up the whole intervening space.

CRUMMOCK WATER.

CHAPTER IX.

THE FOREIGN ROCKS OF THE DEVONIAN PERIOD.

After the Devonian system had been established in England, chiefly on the evidence of fossils, and while Geologists were still disputing the fact of the well-known altered and crystalline slates of Cornwall and Devon being contemporaneous with the Old red sandstone, Professor Sedgwick and Mr. Murchison determined to examine for themselves some of those continental localities, which they imagined might either modify, or more completely establish their proposed classification. For this purpose they left England in the summer of 1839, selecting as the scene of their labours the transition rocks of the Rhenish provinces, where they expected to discover a series of beds intermediate, both in mineral character and palæontologically, between the carboniferous system and the rocks of the Silurian period. And in fact, after careful investigation, they found that among the older rocks of Westphalia, Belgium, and Franconia, there did exist satisfactory evidence of a gradual and unbroken passage downwards to the most ancient fossiliferous strata; but they also perceived, that however it might sometimes be convenient to indicate in particular districts, by special local names, subdivisions and groups of strata locally distinct, yet, that such subdivisions must not be expected to possess other than local value, the whole system notwithstanding being con-

tinuous and unbroken. Further investigation in other parts of Europe, and a more careful examination and comparison of fossils, has since proved that this view is correct, and that, taken as a group, the deposits are remarkable, not less for the extensive area over which they are spread, than for the enormous thickness to which they are developed, and the persistence and striking peculiarities of the fossils by which they are characterised.

But the general results arrived at by Professor Sedgwick and Mr. Murchison will be best understood by the following conclusions, extracted from the memoir published by them in the Transactions of the Geological Society.*

"First. From the great similarity of mineral structure, as well as of fossils, from the common lines of strike and dislocation, and from many other common accidents of position, we concluded that the old rocks on the right bank of the Rhine, between Westphalia and the chain of the Taunus, in the Hartz district, and on the northern flank of the Fichtelgebirge, belonged to one connected series of deposits,—that they all gave unequivocal exhibition of a *Devonian system*,—and that none of the subordinate groups were of any great antiquity.

"Secondly. That the great series of rocks expanded between Westphalia and the Taunus might be subdivided into the following groups, arranged in descending order.

"*c.* A true carboniferous series, partly based on carboniferous limestone in its ordinary form, and partly on alum slate, flinty slate, and thin bedded, black limestone.

"*b.* A series of shales, slates, and limestones, containing many fossils identical with those of South Devon.

"*a.* Masses of slate and other ill-defined rocks, containing Silurian fossils, and forming the base of the series."

* Second Series, vol. vi. p. 224.

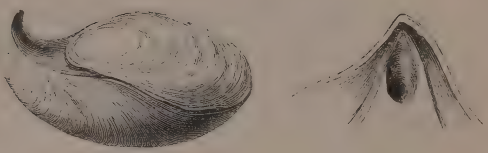
The middle one of these groups (that denoted by the letter *b*) will now come under our consideration, and we shall soon perceive how far the various strata resemble, and how far they actually represent, the Devonian system.

It is chiefly in the north of Westphalia, where limestones exist loaded with true Silurian fossils, that we are enabled to trace, by continuous sections, the nature of the overlying beds, and actually determine the lithological character of the whole series between the Silurian limestones and the true carboniferous rocks.

The beds in this part of the Continent consist of a series of schists and calcareous shales, lying conformably upon true Silurian strata, and containing fossils, of which a considerable number agree with those of the upper beds of the Silurian system, but in which a sprinkling of new forms appears to indicate that a change has taken place, and that the beds are therefore to be classed among the lowest of the Devonian series. They are overlaid by non-fossiliferous sandstones, and these again by a limestone of light grey colour and considerable thickness, characterised by abundant remains of a peculiar fossil, the *Strigocephalus*,* with which several species of corals are associated. This bed is found also to contain many of the best known fossils of the South Devon limestone, to which it possesses so great a general resemblance that, throughout large tracts of Westphalia, the two rocks could not be distinguished from one another by hand specimens.

The fossils are also abundant, and so nearly resembling those of our own country, that this Westphalian bed must be on the same parallel with the great limestone of Devonshire. I shall have occasion to allude to it again under the name of "Strigocephalus limestone."

* See figure, p. 166.



STRIGOCEPHALUS BURTINI. DEFR.

Eifel.

Overlying this bed there is found next a series of black or dark-coloured limestones, and beds of dark shale, with thin calcareous courses, surmounted by red shale, black limestone, and carbonaceous sandstones, upon which the coal measures rest conformably, without any distinctive mark of separation.

In this section, therefore, the decidedly Devonian limestone passes without any break of continuity into the Silurian rocks on the one hand, and the carboniferous on the other; and we find, that the great defect of the Devonshire sections is, in this part of Europe, perfectly supplied, more particularly with regard to the passage of the culmiferous beds into those of the true carboniferous system.

The Strigocephalus limestone, which is so decidedly Devonian as to form an admirable starting point in the Geology of the west of Europe, is again seen at no great distance, but in a reversed position; and on the right bank of the Rhine, between Cologne and Bensberg, a group of strata, several hundred feet thick, is completely inverted. Although by the evidence of fossil remains the sequence has here been made out, the appearance of sections would induce the Geologist to place the highest and newest formations at the bottom of the series, and the lowest, which abut irregularly and unconformably against the carboniferous strata, as immediately succeeding the rocks of

that period. This arrangement is contradicted, however, not only by the fossils, but also by the analogous sections of Westphalia, of Belgium, and the Eifel, and we are obliged to assume, in order to explain these appearances, that the flexure which twisted a portion of the great Westphalian limestone into the valley of the Rhine, at the same time reversed the original position of the whole series.

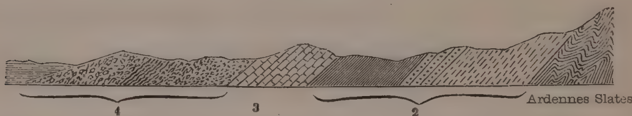
The great extent to which this remarkable bed of limestone is expanded in the west of Europe, and its extreme richness in organic remains, will not be recognised by the observer who merely judges of the importance of a rock by the extent of its colour on a geological map. The interesting localities of Bensberg, Refrath, and Paffrath, (all of them within ten English miles of Cologne,) contain, however, enough of beautiful fossils and geological interest to be well worthy of a visit from the Rhine tourist; and the locality is the more interesting from its exhibiting a passage from the strata at Bensberg, in which Silurian species occur, to those of Paffrath full of Devonian corals and other fossils of the same period.

In the northern part of the Duchy of Nassau, again, about twenty or five and twenty miles from Coblentz, great contortions and extraordinary intrusions of basalt, although they render the Geology extremely complicated, exhibit clearly an extensive and fossiliferous calcareous group reposing on rocks of the Upper Silurian period, and containing true Devonian fossils; the upper beds being surmounted (at Herborn) by a *Posidonia** schist, identical with the lower carboniferous limestone of Westphalia, and resembling the culm limestone of Devonshire.

On the banks of the Lahn (as may be seen on the

* The *Posidonia* is a bivalve shell, which is almost characteristic of a lower member of the carboniferous series.

road between Coblentz and Ems*) the limestones and the associated grauwacké are still more unequivocally Devonian; and here also, although the alternating masses of limestone and schist are of great thickness, and rival in that respect the whole series of limestones and slates in South Devon, there is proof, in following the course of the river, that this calcareous system rests on the true Silurian rocks. The same thing may be observed by tracing the order of superposition on the banks of the Rhine, between Coblentz and the town of Bingen.



SECTION ACROSS THE DEVONIAN FORMATIONS OF BELGIUM.†

But the development of the Devonian strata is not less remarkable on the left than on the right bank of the Rhine, and the beds are here again brought into relation with the carboniferous as well as with the Silurian strata, the series commencing with the oldest and non-fossiliferous slate rocks of the Ardennes, (referred to the Silurian period,) and passing upwards through them to the carboniferous limestone of Belgium in regular and unbroken succession.

The Ardennes slates are succeeded by a series of hard siliceous beds, (see diagram,) containing a number of red conglomerates and flagstones, with arenaceous shales, frequently resembling the mudstones of England, and formerly supposed to correspond to the Caradoc sandstone of Mr. Murchison.

* At Ehrenbreitstein, also, Devonian fossils are occasionally found, although the strata are there much contorted. See the vignette at the end of this chapter.

† 4. Calcareous shales with overlying indurated shale and psammite.
3. Lower limestone of Belgium.
2. Hard siliceous beds and conglomerates.

The whole group is of great thickness and is fossiliferous; but the line of separation by means of fossils has not been clearly made out, the upper part of the mass being unquestionably Devonian, while the lower beds seem to pass into Silurian strata, and contain fossils common to both formations.

The lower limestone of Belgium, overlying this group, is well defined and of great thickness. Both by the evidence of sections and by fossils, it has been ascertained to be contemporaneous with the true Devonian limestone, and it appears identical with that of South Devon, and with the corresponding beds in Westphalia.

Without any break of continuity, or any appearance of interrupted sequence, this limestone is replaced by a rock whose mineral characters resemble, in many respects, those which mark the Ludlow beds, and which was formerly confounded with Silurian strata. It contains, however, no Silurian fossils, and must, on the contrary, be referred to the upper part of the Devonian series. It is composed of alternating beds of an open-grained, yellowish sandstone (*psammite*) and of indurated shale or earthy schist; its total thickness is very great, and in both the lower and upper parts there occur limestone bands, and bands of calcareous shale extremely fossiliferous, and indicating an approach to the carboniferous system.

Lastly, in this part of Europe, the Devonian series passes upwards into the carboniferous by a thickness of as much as 1500 feet of strata, chiefly composed of coarse, yellowish sandstone, sometimes changing to grey micaceous flagstone, and alternating with shales and calcareous beds; indicating clearly that this and the overlying deposit of mountain limestone were absolutely continuous and linked together by a gradual passage.

In the Eifel there occurs a limestone of considerable thickness overlying, but occasionally replaced by, a series of shales more or less calcareous, and which contain a number of fossils hitherto found only in Silurian strata. These lower shales are probably contemporaneous with the upper beds of the Silurian system, but the limestone is Devonian, and on the parallel of the lower Westphalian and Belgian limestones. It is composed of two principal varieties, one of which resembles the Westphalian beds, but the other is dolomitic,* and sometimes hard and crystalline, sometimes cellular and without bedding, and occasionally earthy and incoherent.

As a general rule, the dolomite is found occupying the upper part of the series, and it is, in all probability, common limestone, altered by the intrusion of volcanic matter and magnesian vapours. The whole group is fossiliferous, some localities being much more so than others; the beds are frequently disturbed, and near Münster Eifel they appear fairly inverted.

Passing on now to the contemporaneous beds in the north of Europe we shall find them greatly expanded, and more especially so among the stratified rocks of Russia, where their position has been recently determined by Mr. Murchison. To the researches of that gentleman and his associates, M. de Verneuil and the Count von Keyserling, Geologists are indebted for a knowledge of the Palæozoic rocks of north-eastern Europe.

The Devonian, or Old red sandstone formations of Russia, occupy a tract nearly as large as the whole of the British islands, and they rest conformably upon low plateaux of Silurian rocks, attaining heights of from five to nine hundred feet above the sea level.

* *Dolomite* is a variety of common limestone, chemically as well as geologically. It contains carbonate of magnesia, combined with carbonate of lime, and is usually semi-crystalline in structure, and apparently changed from its original condition.

In different parts of the large tract of land occupied by formations of this geological period, there occur varieties of mineral composition and lithological character quite as great as those already described in speaking of the contemporaneous rocks in our own country and Germany; and the fossils consist of nearly all those which are most characteristic of the different beds in each, together with a few species not met with in western Europe.*

On the flanks of the Ural chain, the Devonian rocks overlying Pentamerus limestones, appear in the form of limestones and schistose beds with grits, the limestones resembling, in their dark colour and sub-crystalline aspect, those of South Devon, and the whole group quite as dissimilar from that occurring in the flat regions of Russia, as are the rocks of the same age in the south-west of England from the conglomerates and tilestones of the Old red sandstone.

In the heart of Russia, again, there exists a great dome-like elevation, which rises to the height of about 800 feet above the level of the sea, and is composed of strata loaded with fossils characteristic of the Devonian system. But these strata are very unlike any other known Devonian beds in their lithological character, being composed of *yellow* and *white* marlstones and limestones, the latter often magnesian, and so accurately resembling the *Zechstein* of Germany (quite the top of the Palæozoic system),—that, were it not for the evidence derived from fossils, they would inevitably be referred to the same period as this latter bed.

The great importance of the Russian Devonian strata in

* As one instance of the varied lithological character of the Russian Devonian strata, we find in an extensive district a series of sandstones and marls of a red colour and containing salt springs and gypsum, like the beds above the whole Palæozoic group in England, but in other respects exhibiting the mineral peculiarities, and containing throughout the fossils of the middle Palæozoic period, as exhibited in Herefordshire and Scotland. Geol. Proc. vol. iii. p. 401.

establishing the order of succession in Palæozoic Geology, consists in their having afforded the first instances of the actual intermixture of fossil remains of fishes, identical with those of Scotland, in the same beds which contain the shells and other invertebrata of Devonshire and the Eifel. This clear and direct proof which had long been anxiously sought for, had never been discovered anterior to the researches of Mr. Murchison and his friends in north-eastern Europe; and no one had observed the evidence there existing, by which the only obscurity that hung over the Palæontology of the older rocks has been completely removed. A great step has thus been gained, and the Geology of Russia has risen at once into a subject of the first importance. Whether, indeed, her boundless plains and slightly consolidated plateaux, or the rocky flanks of the Ural chain be examined, Russia will be found to exhibit a regular ascending series from true Silurian rocks with their most characteristic fossils, through a broad and distinct Devonian zone, up to the undoubted representatives of the mountain limestone. These formations will be found also to exist on an enormous horizontal scale, being consistent over a vast extent of country, and in a future chapter I shall have occasion to point out the steps by which the same region has afforded the means of completely developing the relations of a group of strata which terminate the Palæozoic series in ascending order.*

It is interesting to find that the Devonian system, which occupies so important a place in European Geology, is

* I must once more express my obligations to Mr. Murchison for the kindness with which he has communicated his views on this highly important and interesting subject. A work by that gentleman and his associates, on the Geology of Russia, has been for some time advertised, and will, of course, contain far more copious and exact information, and more minute evidence than could be given in the memoirs read before the Geological Society, the abstracts of which are at present the only documents to be referred to on the subject.

repeated on the continent of America, with nearly the same lithological characters, and the same species of organic remains. In the Western States of North America, towards the Alleghanies, a group of about 150 feet of strata has been described,* strikingly resembling the lower part of the Old red sandstone of Scotland, and containing similar species of fossil fish. These rocks thicken out towards the east, preserving their lithological peculiarities, and attaining a thickness of 1000 or 1500 feet in the neighbourhood of New York, where they pass insensibly into the carboniferous strata.

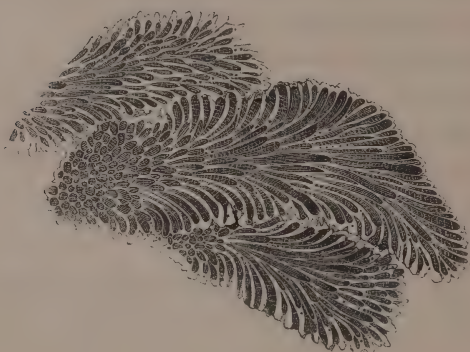
In other parts of North America, as, for instance, in Canada, it seems almost certain that contemporaneous beds exist; and, in all probability, such rocks will be traced over a considerable portion of the globe, when further investigation shall take place by competent Geologists in distant islands and continents.

* Hall. Notes on the Geology of the Western States.—*Silliman's Journal*, xlii. p. 55.

CONTORTIONS OF STRATA. EHRENBREITSTEIN.

CHAPTER X.

THE FOSSILS OF THE MIDDLE PALÆOZOIC PERIOD.



FAVOSITES POLYMORPHUS. Goldf.
Devonian and Silurian.

The fossils of the middle Palæozoic rocks consist partly of numerous corals and the remains of molluscous animals and radiata, differing but little in general appearance from those of the Silurian system; but to these are superadded a large number of other fossils, and amongst them the remains of fishes, which frequently exhibit a perfect outline of the animal, and have been found abundantly in particular localities in the Old red sandstone of Scotland.* In the shales and limestones of

* The bituminous schists of Caithness and the Orkneys, the numerous and rich localities in Morayshire, the classic ground of the Old red sandstone, the beds at

Devonshire and on the Continent, belonging to this period, the remains of several invertebrata, common in the Silurian strata, are still found, though rarely, and they appear to have been soon replaced by others, differing more or less in detail, and doubtless adapted to altered circumstances in the ancient seas. We find, also, that these new species, at first sparingly distributed, became in their turn predominant, and that besides this change, which so far appears to be a mere substitution of one species for another, a large number of species referrible to many new genera were added, and amongst them not less than fifty species of fish, of singular forms, greatly different from those found in the existing seas. These remains, also, are very widely distributed, but appear to characterise particular strata and groups of strata, of the Devonian and Old red sandstone formations.

With regard to the Zoophytes of the middle Palæozoic period, they are chiefly found in calcareous bands associated with the shaly beds, and in the mass of the Devonian limestone itself. The genus *Cyathophyllum*, met with in Silurian strata, is incredibly abundant, and more especially so in some foreign localities, while *Stromatopora*, *Favosites*, and others, are also extremely common throughout the series. Many of the marbles of Devonshire owe their beauty to these organic remains, and some of them are absolutely made up of the work of the coral animal.

The Radiata are, perhaps, still more common in the Devonian than in the Silurian strata, and the Crinoidal family is represented by many species, the existence of

Elgin and those in Forfarshire, (chiefly at Balruddery,) are all celebrated for the great abundance and variety of the fossil remains of fish obtained from them. But the Old red sandstone of Scotland, as a formation, is extremely rich in fossils of this kind.

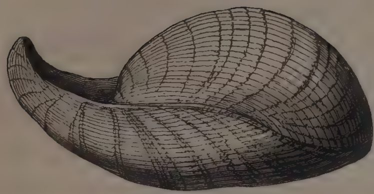
which is attested by innumerable fragments of their skeletons, distributed through most of the Devonian beds in England and on the Continent.

The Crustaceans, also, reappear in the Devonian strata, and are not only represented by different species of Trilobites, some of which, such as *Brontes*, are characteristic and remarkable, but also under a very different form, exhibited in several singular fragments found in the Old red sandstone of Scotland.

TAIL OF BRONTES FLABELLIFER.

M. Agassiz has decided that these remains, at first supposed to belong to a fish, must be those of an extinct species of Crustacean, not unlike a lobster in shape, but whose length, judging by the specimens that have been found, must have exceeded four feet. The claws of this gigantic animal are said to resemble those of a common lobster, to have the same general outline, and to be armed with similar toothlike tubercles. The immense shield which covered the upper part of its body was more angular than in existing species, and was delicately fretted, as if with the markings of circular or elliptical scales, which, however, are mere sculpturings on the surface of the shell. The tail appears to have been continuous, and so large, that a lobster of the ordinary size might stretch its entire length on this part of the extinct species.

The most remarkable forms assumed by the Brachiopodous Mollusca of the Devonian system have already been alluded to, as referred to the genera *Strigocephalus* and *Calceola*, and both of them may be considered characteristic of the Devonian limestones. The first genus (*Strigo-*



PENTAMERUS GRYPHUS. SCHLOT.

CALCEOLA SANDALINA. LAM.

*cephalus**) resembles the Pentamerus in its peculiar structure, and has been considered identical with it by some naturalists. *Calceola* is of an odd pyramidal shape, and differs considerably from the other Brachiopoda. One true species of Pentamerus (*P. gryphus*) is also found in the foreign Devonian beds, and is a remarkable and interesting fossil.

It is not rare to find the remains of many univalve shells in the Devonian rocks both of England and the Continent. They are sometimes extremely perfect, retaining even those markings which seem to have been due to the presence of colouring matter. Three species from the Eifel, two of them nearly allied to existing genera, if not actually referrible to them, are represented in the accompanying wood-cut.

a. BUCCINUM ARCULATUM. SCHLOT.
b. NATICA SUBCOSTATA. D'ARCH. AND DE VERN.
c. MURCHISONIA INTERMEDIA. D'ARCH AND DE VERN

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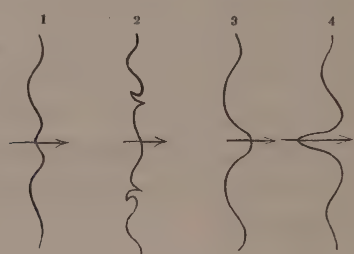
* See *ante*, p. 165.

The Cephalopoda, although not more abundant, are, perhaps, more remarkably different from those of the Silurian rocks than is the case with the other Mollusca. In addition to several distinct species of Orthoceratites, some of which are so abundant as to form almost the sole materials of a limestone found in the north of Bavaria and the adjacent countries, there are also many species of a genus called *Clymenia*,* observed for the first time in the Devonian strata, and forming an important link in the chain which unites the Nautilus with another well known but extinct genus (*Ammonites*), entirely confined to the secondary formations.

The nature of this step is thus explained:—the multilocular shell of the Cephalopod is known to be divided into chambers, or compartments, by certain walls or septa,†



INTERSECTION OF THE SEPTUM WITH THE SHELL OF CEPHALOPODA.‡

each of which, where it meets the surface of the shell, forms a line of intersection, often displayed in the fossil. The nature of the intersection must depend on the form of the septum, and this in the common Nautilus (*N. pompilius*), being simple, and the cavity cup-shaped, the line when

* See the figure in the next page.

† See *ante*, page 140.

‡ 1. Nautilus pompilius. 3. Clymenia.
2. Nautilus sypho. 4. Goniatite.

traced on paper is found to be slightly undulating (see the diagram fig. 1,); but it is easy to perceive, that the shape of the cavity, and therefore of each septum, must depend on the shape of the body of the inhabitant, and the nature of its attachment to the shell. When this is simple, the line of intersection will be simple, but, when it is not, all the complications of the thick enveloping skin called the *mantle*, which deposits the carbonate of lime, must be repeated accurately each time that the animal builds for itself a new wall of separation. Now, according to M. Von Buch, who has paid much attention to the extinct species of Cephalopoda, the object and use of the complexity of this line of intersection of the septum with the shell—in other words, of the numerous recesses and projections in the extremity of the cavity inhabited by the animal—must be sought for in the position of the siphuncle (the tube already described passing through the chambers), and the relative value of that organ as a means of securely attaching the animal to its shell. In the common and well known pearly Nautilus, where the siphuncle is large and in the middle of the septum, it is itself a sufficient means of attachment, and the animal requires little other support. In another species of Nautilus, however, (*Nautilus sypho*,) the siphuncle is near the inner margin, and thus, not being so well placed for securing the animal, the mantle is also attached by certain

CLYMENIA INÆQUISTRIATA. MUNST.
Elbersreuth.

N 2

projections, which hook into recesses of the septum, and produce a line of intersection represented in the diagram (fig. 2), the arrow pointing to the open extremity of the shell.

Such being the case in the Nautilus, let us now turn to the position of the siphuncle, and the nature of the corresponding line in the Devonian genus *Clymenia.* We here find the siphuncle placed quite upon the ventral or interior margin of the septum, and the line of intersection, resembling in some respects that of the *Nautilus sypho*, has, however, unlike that species, a *forward* bend towards the aperture, corresponding to a recession of the upper part of the mantle on each side (fig. 3). When, as in the *Goniatite*, (another genus found in the Devonian rocks and still more abundantly in the overlying carboniferous series,) the position of the siphuncle is dorsal, (or on the outer and upper margin of the septum,) instead of the forward bend above alluded to there is (fig. 4) a reflex wave on the dorsal line, indicating a recession of the mantle, which, in many cases, is frequently repeated, and characterises in a still more complicated form the numerous species of Ammonites so abundant throughout the secondary period.*

We now come to the remains of animals of higher organization, referred to the class Vertebrata; and although, as I have already mentioned, such remains are not abso-

* In a bed of Devonian limestone finely exhibited at Elbersreuth, near the town of Baireuth, in the north-east of Bavaria, the genus Clymenia is extremely abundant, and as many as thirty-five species have been found there, most of them peculiar to the locality. This is, perhaps, the most remarkable instance of the local development of nearly all the known species of a particular genus yet observed among the fossils of the older rocks.

The Clymenia limestone contains also a few Goniatites, and both genera have been found in the fossiliferous rocks of the same age in Cornwall and Devonshire, although not very abundantly.

lutely excluded from the rocks of the older Palæozoic period, the fragments found there are too obscure and imperfect to call for any lengthened account in a description of characteristic fossils. But in the Old red sandstone the Vertebrata are represented by a large number of species often perfectly preserved.

As in fishes the difference is very great between existing species and those found fossil in the older rocks, I shall, according to the method already adopted with the Brachiopoda and Cephalopoda, precede my account of the fossil species by a short outline of the classification adopted in the arrangement of Fishes, and some general remarks on the mutual relations of the extinct and existing forms in this important class of animals.

To discover the order in which fishes may be most naturally classified has frequently been attempted by Ichthyologists; but cannot yet be looked upon as satisfactorily accomplished. The peculiar organs which characterise them, both external and internal, are, indeed, numerous and striking, but the fixing on a small number of the most important of these, and thus forming great natural divisions, in which each species may readily and properly be arranged in the series, is a point to which the attention and efforts of naturalists may still be directed with great advantage to Natural History.

The multitude of new species determined of late years both by the more careful investigation of the fishes of existing seas, and also by the discoveries of the Palæontologist, have added considerably to the difficulties with which the subject is surrounded.* The fossils, also, that

* Upwards of one thousand species of fossil fish had been determined by M. Agassiz up to the year 1836, five hundred of which were discovered within the three preceding years.

have been obtained from almost every group of strata, but more especially from those of the Palæozoic period, present so many new forms, and such extraordinary and almost incomprehensible analogies and differences, that in spite of the long-continued and invaluable labours of M. Agassiz, (a Naturalist thought worthy by Cuvier to continue the investigations he had commenced, and carry out his views in this department of Natural History,) it cannot yet be safely concluded, that we have discovered the true principles of classification in Ichthyology; or that the ingenious system proposed by M. Agassiz, singularly useful as it is when applied to determine fossil species, is really natural, and will prove sufficient for the general purposes of science.

There are several remarkable peculiarities in the structure of fish, some one or other of which has usually been neglected in each attempt to discover the natural order of arrangement. It has been long known, for instance, that while several species, such as the perch and the salmon, are provided with a perfect bony skeleton, others, like the shark and ray, possess a vertebral column simply cartilaginous and not containing any real bone, although earthy particles are secreted and made use of by the animal, in providing bony plates to cover the head and the anterior portion of the body.

Cuvier also observed, that two very extensive groups of fishes, having, in many respects, singular and important analogies, were distinguished from one another by the existence or non-existence of spines placed on the forepart of some of the fins. These spines are found in the perch, the mullet, &c.; while other genera, such as the salmon and the eel, have their fins entirely soft.

The nature of the classification of fish adopted by

Cuvier, and founded on these peculiarities of structure, may be thus understood:—

First—He collected the whole number of species into two groups, according to the nature of the skeleton and the hard parts, the one group containing the *bony* and the other the *cartilaginous* fish. Secondly—He made use of the fins or organs of locomotion to separate the first group into two parts, and applied the name *Acanthopterygian* (or thorny finned) to the one, and *Malacopterygian* (or soft finned) to the other. This method, however, does not seem to meet the wants of the Ichthyologist, and will probably be partly, if not entirely, superseded by the system of M. Agassiz, founded solely on external characters.

M. Agassiz, excluding all consideration of the organs of locomotion and the nature of the internal skeleton, and looking on the scales, which form a kind of external skeleton, as indicating the habits and peculiarities of the animal, has taken this one point of structure as the foundation of his system: stating that the skin and its appendages are the organs which more distinctly than any others show the relations of an animal to the element in which it moves, and that they occupy in fishes a still more important post than in other vertebrata, and correspond to the teeth of Mammalia and Reptiles, in being those organs on which all others are dependent.

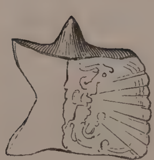
It is certainly true, that in many fishes the scales do form an external skeleton, and are coated with hard enamel, so that after the bones have decayed, and altogether disappeared, these remain and preserve the exact form of the animal in a fossil state; and it cannot be questioned that M. Agassiz, in appreciating and directing especial attention to the scales, as characteristic parts of the structure of fish,

has conferred a great benefit on Palæontology, and one which can hardly be too highly estimated. Whatever may be the amount of recognition which his system of classification may receive from the Zoologist, it must long remain of the highest interest to the Geologist, and one with which he will endeavour to make himself familiar, as being a powerful aid, if not an unerring guide, in identifying species.*

The following sketch will give an idea of the nature of the principal subdivisions proposed by M. Agassiz: the further details it is not necessary to consider, nor are they as yet completely explained.

CLASS IV. PISCES.

FIRST DIVISION.—FISHES WITH ENAMELLED SCALES.

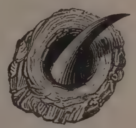


Order 1. Ganoidians (*γάνος, splendour*). The fishes of this order are covered by angular scales, composed internally of bone, and coated with enamel. The scales are *regularly* arranged, and entirely cover the skin.

The *Sauroid fish*, or those which, from the structure of their teeth and other peculiarities, approximate to the reptiles — the *sturgeons* and the *bony pike* (a remarkable fresh-water fish found in the North American lakes, and presenting singular analogies with extinct species,) are among the most interesting fish of this order. Nearly all the species referred to it are now extinct.

* It is an interesting fact, that one of the first applications of his new views of the classification of fishes enabled M. Agassiz to determine the geological age of a stratum whose position in the sequence had not before been made out correctly. In the canton of Glaris, in Switzerland, there are found slates perfectly identical in mineral character with those of the older Palæozoic period, but containing the remains of fossil fishes, and M. Agassiz identified many species of these fishes with others found in the Cretaceous rocks of Bohemia. There is now no doubt that the Glaris slates belong to the Cretaceous system.

ORDER 2. PLACOIDIANS (πλὰξ, *a broad plate*). This order contains fish whose skin is covered *irregularly* with plates of enamel, often of considerable dimensions, but sometimes reduced to small points, like the shagreen on the skin of the shark, and the prickly tubercles of the ray.



All the "cartilaginous fish" of Cuvier, with the exception of the sturgeon, are included in this order, and amongst the whole number of species the various tribes of *sharks* and *rays* occupy an important place.*

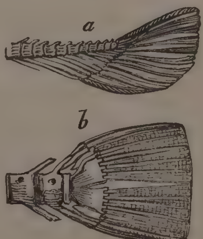
SECOND DIVISION.—SCALES NOT ENAMELLED.

ORDER 3. CTENOIDIANS (κτεὶς, *gen.* κτένος, *a comb*). The Ctenoid fish are covered with horny or bony scales, jagged like the teeth of a comb on the outer edge. The *perch* and many other existing genera are of this order, which contains but few fossil forms.

ORDER 4. CYCLOIDIANS (κύκλος, *a circle*). The fish of this last order have their scales smooth and simple at

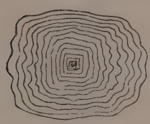
* Many of the fish comprised in these two orders are marked by a peculiarity which seems to indicate an approximation to the Saurian type. This consists in the prolongation of the vertebral column into the caudal fin, forming what is called a *heterocercal* tail.

In all recent fish, with the exception of the shark family, the sturgeon, and the bony pike, the vertebral column of the fish terminates at the point where the caudal fin is given off, and this fin is expanded above and below the body, forming what is called a *homocercal* tail. In all those, without exception, whose remains have been found in strata of the Palæozoic period, the caudal fin is heterocercal, being formed of two unequal branches, the upper one expanded immediately from the vertebral column, while the lower one is given off at a point some distance from its extremity.



a. HETEROCERCAL TAIL.
b. HOMOCERCAL TAIL.

the margin, and often ornamented at the upper surface.



The *herring*, *salmon*, &c., are referred to the Cycloid order, and this, with the former, includes almost the whole number of existing species.

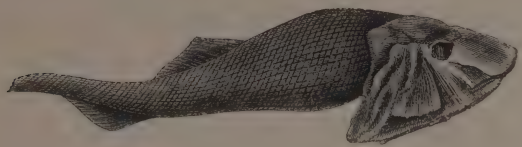
The fish of the Palæozoic period, belong, as I have said, to the first of these divisions; and of eighty Ganoid species, which are all that have been hitherto described, upwards of fifty are exclusively met with in the Old red sandstone formation. Some of the more striking peculiarities of the structure and appearance of these species I shall proceed to describe, after having said a few words on the fragments occurring in the rocks of the older Palæozoic period.

The Silurian fish appear to have been small, but extremely carnivorous, in one genus the teeth being bristled with sharp points, and in another the shape of these important organs offering clear indications of voracious habits, while the defensive fins possessed by them (which are comparatively very large) indicate no less clearly, that even at that time powerful enemies were to be avoided or resisted. From the rarity of their remains, however, the fish, during the Silurian period, do not seem to have been so important in the scale of the animal economy as they afterwards became, and the fragments of teeth, jaws, scales, and defensive fins, although abundant in some spots, are not spread through the formation, nor have any been found as yet in the lower beds.

The fossil fish of the Middle Palæozoic period are chiefly found in the Old red sandstone of Scotland;* and the different genera, most of which belong to the Ganoid

* Most of the characteristic species have also been met with from time to time in the contemporaneous beds in Herefordshire, but always in imperfect and fragmentary portions. The sandstones of Russia have recently furnished Mr. Murchison with some remains of the same kind, and of identical species.

order, have been formed by M. Agassiz into four groups, of each of which it will be necessary to offer some account, as they are marked by very singular characteristics.



CEPHALASPIS LYELLII. AG.

In the fish of one of these groups, the head is developed to an enormous size, and is covered with large plates, which likewise extend over a considerable portion of the trunk, while in some of the genera, moveable appendages placed at the side of the head, gave them a most remarkable appearance. The different genera have been called *Cephalaspis*, or buckler-headed; *Pterichthys*, or winged fish, and *Coccosteus*.

The *Cephalaspis* is one of those extinct animals of which there may at first seem some question as to its position in the scale of nature, but according to M. Agassiz, there is no doubt of its being a true fish. Its remains are found chiefly in the upper beds of the Old red sandstone of Scotland, but also in Herefordshire and Wales.

In this genus the head is very large in proportion to the body, and occupies nearly one-third of the entire length of the animal; its outline is rounded and crescent-shaped, and the lateral horns slightly incline towards each other, their points being nearer to one another than they are to the round part of the snout. The middle of the head is elevated, and the sides dilated, so as to overlap the body, and extend considerably behind it; but perhaps the head only appears to extend so far, owing to accidents of displacement since the death of the animal. The eyes are placed

in the middle of the shield, near to each other, and are directed straight upwards. It is imagined that the pointed horns of the crescent may have been useful as defences when the fish was attacked by the powerful cephalopods which inhabited the ocean at the period of its existence.

The exterior surface of the head is covered in a great measure by irregular scales, of a more or less rounded shape, the edges of which are united, so as to form a kind of pavement. These scales are bony, and coated with enamel, having a convex centre, and hollow furrows diverging towards the edge. The whole of the head appears to have been encased in bony plates of fibrous structure, which exhibit the hinder and middle portion of the head of a square form, the occipital crest being very prominent.

The form of the body is that of an elongated spindle, swelling out towards the head, and narrowing insensibly towards the tail, which is proportionably very slender. There are impressions of two dorsal, an anal, and a caudal fin; but, with the exception of the second dorsal, they are somewhat obscure. The body is covered with scales of peculiar and varied shapes, one range of high and narrow plates being inserted transversely along the middle of each side, while on the back and belly there are series of little scales disposed obliquely, and others still smaller, and of rhomboidal form, on the tail.

The description above given, although for the most part that of the genus, belongs more particularly to the species figured (*C. lyellii*).

In another species (*C. lloydii*), the head is still less like that of any known fish, and the marks on the enamelled plates of the skull resemble the lines of growth on the shells of some species of mollusca, while the general structure of the head seems to offer analogies with the crusta-

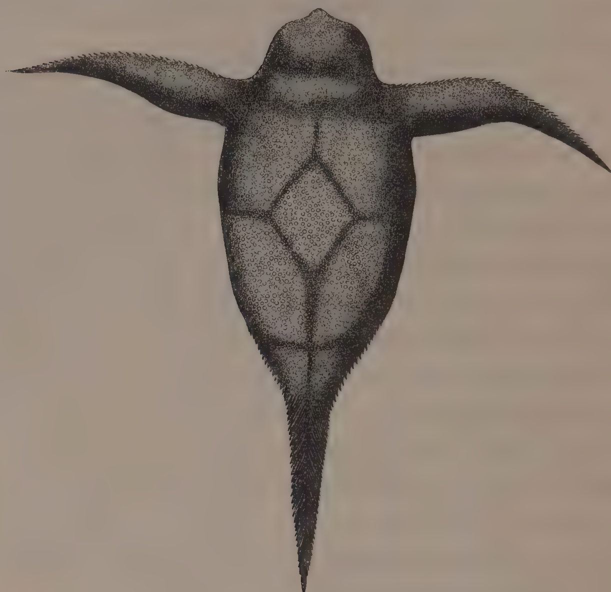
ceans, and the whole appearance of the fossil approximates so nearly to that of certain trilobites, that at first even M. Agassiz seems to have found some difficulty in determining its true analogies.

The two genera, Pterichthys and Coccosteus, are not at all less remarkable in form, or more like any existing fish, than the Cephalaspis, and they are so strangely anomalous in their structure, as to have puzzled and confounded all those who first examined them. They are, however, fish; but the scales with which they are covered appear like the shells of crustaceans, and their peculiar fins, the shape of the head, the manner in which the tail is extended, and its proportions, completely distinguish them in appearance from any other animals. Of the two genera, seven species of Pterichthys and five of Coccosteus are known, and they are found both in the Orkney islands and on the Elgin and Banffshire coast. The largest size to which they attained does not seem to have exceeded two feet, and their ordinary dimensions are much smaller.

The appearance of the *Pterichthys* is sufficiently remarkable. The body is of considerable depth, the under part flat, and the upper part rising into a kind of ridge along the back, but the whole covered with a strong armour of bony plates. These consist, on the under side, of five, the middle one being diamond-shaped; but on the upper side there are six principal plates on the body, besides those which cover the head. All the plates are thickly tuberculated outside with wart-like prominences of enamel, and their internal structure is bony.

The head is covered by one hexagonal plate, (like the plates on the body,) surrounded by several others of smaller dimensions, separated from the principal one by deep channels. The eyes are in front, and the mouth

appears to have opened, as in many fishes, along the edge of the snout.



PTERICHTHYS. AG.

The tail attached to this strange body, and the wing-like fins, from which the genus takes its name, are not less curious than the body itself. The fins are placed so far forwards, and are so large, as to give a very disproportionate appearance to the body, and their shape adds to the strange effect, for they gradually increase in breadth from the point of their attachment, swelling out until they are somewhat suddenly rounded off, and terminating in a kind of hook, or strong curved point. The tail occupies more than a third of the total length of the animal, and is straight, pointed, and covered with small tuberculated angular scales. It appears to have been supported by a continuation of the vertebral column, and rib-like processes

stand out as if from the vertebræ, making an acute angle towards the extremity of the tail. Most probably the tail was employed as the principal organ of locomotion, the pointed fins being elevated at the approach of danger, and the animal in this way rendering itself as unapproachable and as difficult to be swallowed as its form would admit of.

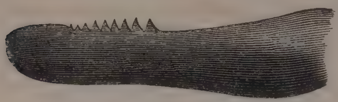
The *Coccosteus* resembled the Pterichthys, both in the nature of its armour of thickly tuberculated and enamelled bony plates and also in the structure of its tail, but differed from that genus in many important points.

CENTRAL DORSAL PLATE OF COCCOSTEUS.

The head of the Coccosteus is rounded, and the bony plates are arranged upon it with singular beauty. The body is of a triangular shape, tapering away towards the tail, and is covered almost entirely by a central plate, much larger than any of the others, having a continuous ridge along the middle of the back. Two small plates on either side fill up the vacant space, and a long vertebrated tail terminates the figure. A couple of defensive fins, as in Pterichthys, were attached to the anterior portion of the animal near the head; but they rarely remain in the fossil, and seem to have been readily broken off after death.

The under part of the body has not been well shown in any specimens yet obtained, but it probably resembled the corresponding part in Pterichthys, except that it was more elegantly studded with tubercles of enamel. Fragments of the central lozenge-shaped plate are occasionally found detached; it must have been of great beauty, but the specimens are mostly too imperfect to enable us to connect it with the other plates.

The jaws and teeth are particularly interesting in Coccosteus, as presenting a very simple form of these organs, the teeth being chiselled, as it were, out of the solid bone of the jaw, just as the teeth of a saw are cut out of a plate of steel. This structure more resembles that of the mandibles of a beetle, or the nippers of a lobster, than the jaws of a fish, and it appears that there is also another still more striking approximation to the crustacean type, in the position and opening of the jaws, which are said to be vertical, and not horizontal.



JAW AND TEETH OF COCCOSTEUS.

Although specimens of the Coccosteus are rarely found perfect, it appears nevertheless to be one of the most common of all the fossil fish of the Old red sandstone; and Mr. Miller, speaking of its remains, observes—"In a few square yards of rock I have laid open portions of the remains of a dozen individuals, belonging to at least two species, in the course of a single evening." These two species differ chiefly in the proportions of the body, the one being much more powerfully and compactly formed than the other.

Another group of Ganoid fish is readily distinguished by the enamelled scales being so small as to give the skin the appearance of shagreen, and, in the establishment of the genera of this group, the singular way in which the fins of some species are sustained by spinous rays is a remarkable and important character. One genus, *Chiracanthus*, includes a small and elegant fish, of whose scales perfect specimens have been frequently found, while the invariable absence of all marks of osseous structure indicates that the skeleton must have been eminently cartilaginous. The body was covered with small angular scales, brightly

enamelled, diminishing in size towards the head; the tail and caudal fin appear to have been large and powerful, and the other fins small and weak; but their structure is peculiar, and they seem to have been formed of one spine, and a membrane thickly covered with minute scales, which extended between the spine and the body of the fish.

Another, nearly allied to this, is described by Mr. Miller as being of small size, (not more than a couple of inches in length,) but provided with spines of singular beauty, resembling a bundle of rods, each rod gradually tapering to a fine point. It is probable that in this genus, as in Chiracanthus, the membrane, which in the fossil appears to extend from the single spine to the body of the fish, unsupported by any framework of rays, may have been provided with a cartilaginous skeleton in the living animal; but it is interesting to find, as we do, the whole shape of the animal preserved and handed down for our examination, in spite of the total absence of those portions of the body which, in other species, are the only ones preserved. The advantage of being able to make use of the scaly integument as a means of classification is here manifest; and there can be no doubt that in these animals it really requires to be considered as one of the most important peculiarities of structure.

The *Chirolepis* is a third genus whose remains are found associated with those of Chiracanthus, but some of the species attained a larger size, the length varying from four to fourteen inches. All the species are remarkable for the number and magnitude of the fins on the under part of the body, and also for the comparatively small size, and the extremely delicate sculpturing of the scales, which are deeply chiselled on the exposed margin. The Chirolepis differs from the former genera, in having a considerable

development of osseous structure exhibited in the plates of the head and the rays of the fins; but no remains of an internal skeleton appear, and the bones of the head are coated with enamel. These bones, as well as the rays of the fins, have their edges jagged, and are covered with little prominences, presenting a very beautiful appearance.

A third group from the same rich localities in the north-east of Scotland, includes three or four genera, of which the vertical fins on the back and under the tail are double, and nearly approach the tail. One of these genera, the *Dipterus* of Cuvier, was the first of the Old red sandstone fish described, and was named from the peculiarity which is now known to characterise the whole group.* Another nearly allied genus has been called *Diplopterus*.

The Dipterus and Diplopterus nearly resemble one another, but the head of the latter is larger in proportion, and the width of the mouth greater. The jaws of each are amply provided with sharp pointed teeth, the head is covered with enamelled plates, which form a kind of case, composed externally of bone, and internally of cartilage, and both are provided with a powerful tail, and large double caudal fin, the rays of this and all the other fins being enamelled, and, together with the scales and bony plates, thickly marked with small punctures.

The genus *Glyptolepis*, another of the same group, is singularly different from the two just described, having all the fins, and also the scales, of such large proportionate size, as to be quite characteristic. The tail is long and spreading, the rays and fins also long and numerous, and although comparatively stout at the base, extremely slender at the termination, and the scales are so large that, in an

* Geol. Trans. 2d Ser. vol. iii. p. 142.

individual whose total length is not more than six inches, the diameter of each scale will be nearly half an inch. The teeth are very minute, and the plates of the head, as well as the enamelled surface of the scales, are ornamented with thread-like sculpturings, whence the name of the genus was derived.

The *Osteolepis*, also nearly allied to the former genera, was a very beautiful animal, the entire head having been covered with bony plates coated with the hardest enamel, and not clothed with flesh or skin. This peculiarity is common to many true cartilaginous fish, where bone appears, indeed, to have been deposited, but the usual position of bone and cartilage was reversed, the bone being exterior and the cartilage interior. The gills were arranged in continuous lines, each being covered by a large plate of bone (the *operculum*), coated with enamel, and without skin. The fins were composed of numerous bony rays, jointed to give flexibility, and, like the body, were covered with enamelled scales. The mouth opened below the snout, and was thickly furnished with sharp teeth. The length of the animal varied from six inches to a foot, and at least four species are known.

The last group of Old red sandstone fish contains two or three genera, evidently the pirates of their day, and characterised by large conical teeth, (situated on the margin of the jaws,) between which are smaller ones of extreme fineness, and close together. Of all these genera, the *Holoptychius* was the most remarkable; and it is the one which seems to have been introduced the last of the group, passing upwards into rocks of the newer Palæozoic period. It was a fish considerably larger than the others, measuring nearly thirty inches in length, without the tail. Its breadth also was considerable, amounting to twelve inches.

The most striking peculiarity of this fish, and that from which the name is derived, is seen in the large undulating furrows marked on the enamelled surface of the scales.* The scales consist of thick elliptical plates, usually an inch and a half broad, and an inch long, and having a smooth border on the upper side next the attachment, where each scale is overlapped by part of three others. The exposed portion is entirely covered with detached tubercles, and part of it also by deep furrows which run in wavy lines to the outer margin. The under side of each scale is porous, and of simple structure.

The head of Holoptychius was small compared with the size of the body, and was enclosed within bony plates, their upper surface covered with rough tubercles of enamel. The jaws were composed likewise of bone, whose outer surface was polished, coated with enamel, and unclothed with skin. A row of thickly set, pointed teeth fringed the enamelled edges of the mouth, and corresponded to the lips of ordinary fish, while within this, there was a second and wider range of teeth, at least twenty times the bulk of the others.

The operculum, defending the aperture of the gills on each side, consisted of one tuberculated and enamelled plate, with a smooth border, on which the upper edges of the occipital plates seem to have rested. The fins have not yet been completely made out; the position of the dorsal and caudal fins is not known, but the ventral fins appear to be placed nearer the tail than is the case in any other fish of the Ganoid order. The rounded form of these fins, and the manner in which their rays are insensibly prolonged, coupled with their relative thinness, are also very

* See the figure at the end of this chapter, which very accurately represents, of the natural size, a beautiful specimen in the Geological Museum at Cambridge.

marked distinctions. Towards the tail, and at the ventral fins, the scales are diminished suddenly to about one-fourth of the size of those on the upper part of the body; the fins themselves are covered at their bases with scales still more minute, and from the bases the rays which form the fin diverge and terminate in a semicircular outline.

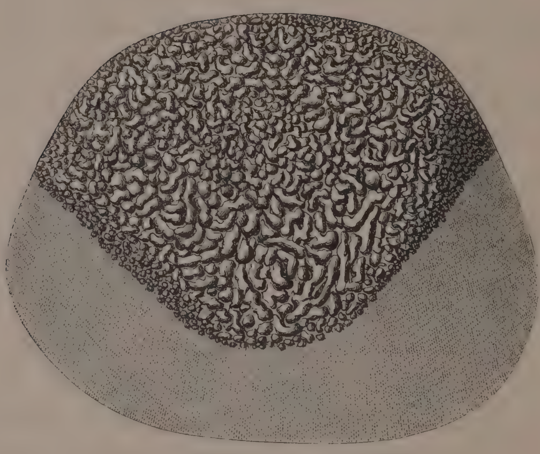
The magnificent specimen which has enabled M. Agassiz and other naturalists to give the detailed account of Holoptychius, from which the foregoing description is taken, is said to be of unrivalled beauty. The animal appears to have sunk quietly to the bottom of the sea after death, and thus lying on its back in the sandstone, there is only seen so much of the head as extends from the upper part of the belly to the snout. The belly itself is thickly covered by the large scales already described, which, by their strength and magnitude, seem as if they might have served for the armour of a crocodile of five times the size of the fish. The creature lies evenly on its back, the ventral fins have fallen equally one on each side, and the whole of the under surface of the body, with the exception of the tail, is fairly spread out for examination. The structure, both of the scales and bones, is so singular and anomalous, that the supposition that they must have belonged to some great saurian—a conjecture offered on their first discovery—was neither unreasonable nor improbable.*

Before concluding the subject of the Old red sandstone fishes, I ought to allude to the gigantic bones of animals of this kind found by Professor Asmus in the Devonian marls and sands of Dörpat, and originally supposed to belong to

* I must here acknowledge my obligations to the account, by Professor Agassiz, of the Fossil Fish of the Old Red Sandstone, published in the Report of the British Association, for 1842. I have also been much indebted to the amusing descriptions of Mr. Miller, already referred to.

Saurians. A single bone of one of these remains is nearly three feet long, and, according to the estimate of Professor Asmus, the fish of which it is a part must have had, when entire, a length of not less than thirty-six feet. Casts of these gigantic fossils have been presented to the British Museum, and, also, to the Geological Society of London.*

* Geol. Proc. vol. iii. p. 719.



SCALE OF HOLOPTYCHIUS.

(*Natural size.*)

THE NEWER PALÆOZOIC PERIOD.

CHAPTER XI.

THE CARBONIFEROUS SYSTEM OF THE BRITISH ISLES.

Among the rocks of the newer Palæozoic period are included all those which occur between the Old red sandstone and the upper New red sandstone of English Geologists, and the general sequence, as it has been made out by investigations in different parts of England, is expressed in the following table:

Newer Palæozoic Period.	Magnesian Limestone, or Permian System.	7. Magnesian limestone.
		6. Lower new red conglomerate.
	Carboniferous System.	5. Upper coal grits.
		4. Coal measures.
		3. Millstone grit.
		2. Carboniferous or mountain limestone.
		1. Lower carboniferous shale.

Our attention at present will be confined to the older of these two systems, and therefore to the lower part of the newer Palæozoic group.

The Carboniferous System in England consists of a widely extended series of highly fossiliferous limestones, alternating with sandstones and shales, the latter frequently containing a large number of the remains of vegetables, which in some cases are so abundant as to form valuable seams of coal. The relative position of the different rocks with respect to the coal is not constant, but, as a general

rule, the order represented in the above table will be found to obtain throughout England.

The actual distribution of the strata of the carboniferous period will be best understood by consulting a geological map, and comparing the following description with the colours which there represent the formation.* In the south-west of England the culm measures of Devonshire, already referred to, rest conformably on the newer Devonian rocks, and represent the older strata of the carboniferous period. The great Pembrokeshire coal-field, with its anthracite, also reposing in a basin-shaped depression in the Old red sandstone, seems to have been once connected with the Devonian culms, and to be only separated from them now by the intersection of the Bristol channel.

From Bristol to the south of Derbyshire the formation is exhibited from point to point, sometimes pushed up through the newer beds, and sometimes resting in troughs in the older ones; and thence it may be followed almost uninterruptedly into Scotland, through a district nearly two hundred miles in length, and having an average breadth of more than forty miles.

In this tract, much greater than is occupied by any other single formation in England, are included the important coal districts of Yorkshire, Lancashire, Durham, and Northumberland, and, by means of the mountain limestone skirting the flanks of the Cumberland and Westmoreland hills, that of Whitehaven is also brought within the group. In Scotland, the valley of the Clyde contains another similar series; and a large proportion of Ireland is occu-

* See the map recently published under the superintendence of the Society for the Diffusion of Useful Knowledge. In this map the separation of the lower part of the New red sandstone, and its association with the newer Palæozoic rocks, is for the first time clearly marked.

pied by rocks of the same date. The whole may conveniently be described under five principal heads, namely, (1) the Devonian culms; (2) the South Welsh coal district, and the small coal-fields in the middle and west of England; (3) the Carboniferous system of the north of England; (4) the Scotch, and (5) the Irish carboniferous deposits.

1. THE CULM MEASURES OF DEVONSHIRE.

The culmiferous series of Devonshire occupies a great trough, the axis of which ranges east and west and extends for about fifty miles, with a breadth of between thirty and forty miles. Crossing the edge of the trough, the upper beds of slate of the Devonian period are found to be replaced by black limestone, overlaid by siliceous flagstones; and these are followed by sandstones and carbonaceous and calcareous shales, which gradually become harder, and pass into siliceous bands of a dark colour, with earthy carbonaceous partings,* surmounted by a regular thick-bedded sandstone, resembling the gritstones of the coal measures.

The beds, the order of whose superposition has been just mentioned, form, with a black carbonaceous shale and a black limestone, the lower subdivision of the whole carboniferous system, as developed in the south-west of England. The order is somewhat different, however, towards Dartmoor, for there an irruption of granite has taken place since the deposition of the strata, and the vicinity of the igneous rock has produced confusion and violent distortion.†

* This part of the series is remarkable for the extreme abundance of an argillaceous mineral, called *Wavellite*, very beautiful specimens of which are found in it, crystallised with a fibrous radiated structure.

† See diagram, page 156.

Notwithstanding this, and the frequent repetition of these beds by faults and disturbances, they are satisfactorily proved to be of great thickness; but they contain few fossils, and differ in lithological character from the rocks, probably of the same age, in the middle and north of England.

The upper culm measures of Devonshire are the newest beds of the district, and occupy nine-tenths of the whole surface of the carboniferous deposit. This group is composed of sandstones and indurated shales (the latter containing the *culm*), and is of great, but unascertained thickness, being perpetually interrupted, coiled upon itself, and repeated over again, forming an incredible number of anticlinal and synclinal lines, all of them ranging east and west, parallel to the strike of the beds.

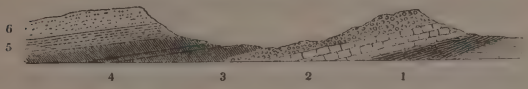
There is, however, no difficulty with regard to the general order of superposition, or the extent and real thickness of this part of the deposit, for both on the northern and southern outskirts of the formation a great ascending series is seen, throughout the whole of which the dip is tolerably regular.

The sandstones of this group are generally close grained, and of a grey or greenish grey colour, passing occasionally into flagstone and laminated arenaceous shale, with fine ripple marks at the partings. The shales vary in appearance from sandy beds to soft slaty clays, not to be distinguished from the common coal shales; and amongst these latter are occasionally found dark carbonaceous bands (the *culm*), containing innumerable obscure vegetable markings, discoloured by pyrites.

Such are the prevailing characters of the beds which form the culmiferous series of Devonshire: these beds are unquestionably the true representatives of the carboniferous

system, and they overlie and succeed regularly to the slates and other deposits of the Devonian period. Notwithstanding the general paucity of fossils, one or two species of shells are not to be distinguished from species well known in the mountain limestone; and the result of a comparison of the remains of plants from the culm, with those commonly met with in rocks of the carboniferous period, tends yet more strongly to establish the contemporaneity of the two deposits. Considering the thickness of these culm measures in Devonshire, they might represent the whole mass of the mountain limestone; and the different mineral character of the rocks, dependent on the circumstances under which they must have been respectively formed, might account for very considerable alterations in the fossils, and must have had great influence in modifying the forms of animal life.

2. THE SOUTH WELSH COAL-FIELD, AND THE DETACHED CARBONIFEROUS DEPOSITS IN THE MIDDLE OF ENGLAND.



THE CARBONIFEROUS SYSTEM IN THE MIDDLE OF ENGLAND.*

The South Welsh Coal-field, like the culmiferous series of Devonshire, occupies a basin-shaped depression in the older rocks, but rests on the conglomerates of the Old red sandstone, instead of the schistose beds of the Devonian system. The basin is cut off by the Bristol Channel to the south-west, and reaches eastward as far as the town of Pontypool, extending thus about ninety miles along the coast of Glamorgan, Caermarthen, and Pembroke. The greatest

* 6. Lower new red sandstone.
5. Upper coal grits.
4. Coal measures.
3. Millstone grit.
2. Carboniferous limestone.
1. Lower carboniferous shale.

breadth is at the eastern extremity, where it measures twenty miles across, but towards the sea this is reduced to five or six miles. The eastern part contains bituminous coal, and is partially cut off by a line of hills from the western district, in which there is found a non-bituminous coal, called anthracite, much more resembling the culms of Devonshire than any other carboniferous deposits of England.

The northern and eastern edges of the South Welsh basin are composed almost entirely of reddish conglomerate —the uppermost member of the Old red sandstone—and this is overlaid by a series of conglomerates and sandstones of the millstone grit (3), see diagram, which here forms the base of the coal-field. In Pembrokeshire, however, bands of carboniferous (or mountain) limestone (2) occur below the millstone grit, and in other districts the transition to the older rocks is made by a series of limestone shales (1) underlying the limestones and sandstones.

The complete sequence from the uppermost beds of the Old red sandstone to the coal of the South Welsh district, consists of two beds of calcareous shale, very similar to one another in lithological character, but with an intervening limestone, which sometimes attains a thickness of five hundred feet. The upper shale passes by regular gradations into the millstone grit series, upon which are placed the whole central area of the coal measures. Coal is never found in any abundance or of great value in or below the millstone grit in the middle of England or in South Wales, although in the north of England, as will presently be seen, no such rule holds good.

The coal-bearing strata of Pembrokeshire and Caermarthenshire consist of numerous alternations of shales and sandstones, with beds of coal. The number of the coal

bands is very considerable, and their thickness, varying from one and a half to nine feet, forms an aggregate of ninety-five feet.* But a small part of this valuable store of mineral produce has as yet been extracted, and the workings are chiefly carried on in the upper beds, whence the coal can be raised at an exceedingly small expense.

In addition to the importance which the South Welsh coal-field derives from its great superficial extent, its thick and numerous beds of workable coal, and the facility of obtaining the coal, it is no less distinguished as the most important depository of iron ore in England. Here, as in Staffordshire and Scotland, the ore is found in nodular masses, regularly bedded and interstratified with the coal and the underlying shales. The ore and the fuel are taken from the same mine, and the limestone, required as a flux, is also close at hand; so that, although the ore is by no means rich, it is found practically to be of greater value than the far more prolific ores of other districts.

The smaller detached carboniferous deposits of the middle of England are of extremely great local importance, and well deserve careful investigation and detailed description; but in a work like the present it would be out of place to enter on the consideration of the minute points of difference by which they are characterised. I shall pause only to direct the attention of the reader to a few of the principal among them, such as, for instance, the Somersetshire and Bristol coal-field, which offers, on a small scale, a beautiful sequence of the whole carboniferous period; the South Staffordshire, which is of great importance in an economical

* According to Mr. Logan, "the coal measures of South Wales attain, in the deepest part, the great geological thickness of 12,000 to 13,000 feet, and contain nearly a hundred thick and thin seams of coal, measuring a foot and upwards in thickness, about one-half of which have been more or less worked."

point of view, and one or two others, remarkable chiefly for stratigraphical peculiarities.

The axis of the Mendip Hills, in Somersetshire, is formed of some of the upper beds of the Old red sandstone, which have been pushed up on both sides of the carboniferous rocks, throwing them into a small basin, well exhibited in the neighbourhood of Bristol. The mountain limestone occupies the lower part of the basin, and is here a blue carbonate of lime, devoid of coal, but extremely fossiliferous.

The millstone grit is of no great thickness, but distinctly marked, and composed of coarse quartzose sandstone; while the coal measures consist of between fifty and sixty seams of coal, alternating with the usual shales and grits; the thickness of the workable beds being three or four feet, and the rest for the most part much thinner.

The South Staffordshire coal-field is remarkable in a geological point of view, for the absence of the mountain limestone and millstone grit, and the immediate superposition of coal measures on the Silurian limestones; and it differs also from other formations of the same kind by having a great preponderance of shales, and few intervening beds of sandstone. It is quite clear that the circumstances of deposition must have been different, but the nature and extent of the difference it is not so easy to discover.

The coal measures in Staffordshire are thus the only representatives of the carboniferous system, and they are almost entirely made up of shales, alternating with seams of coal and ironstone. The number of coal seams is only eleven, but the main bed in the middle of the deposit is upwards of thirty feet in thickness, and it comprises, in fact, several beds of coal, separated by partings of shale, so thin that the whole is worked together. This *ten-yard*

coal crops out near Bilston, and extends from thence entirely across the southern half of the coal-field, where it forms the principal object of mining operations.

Overlying the coal, a peculiar greenish-coloured grit is found in this part of England, sometimes in moderately thick strata, but often expanded enormously, and forming a connecting link between the coal measures and the superincumbent beds. From the composition of this rock, and the quantity of scoriaceous matter it contains, Mr. Murchison has considered it to be a kind of volcanic grit, formed by the detritus of sub-marine volcanoes, which were in activity towards the close of the period of the accumulation of the coal measures.

The northern portion of the Staffordshire coal-field is also interesting, as abounding in well preserved impressions of plants, and also containing a considerable number of animal remains, which are chiefly found in beds of dull black bituminous shale. The animal remains consist of several species of freshwater shells and fragments of fishes; the latter resembling similar fossils much more abundant in the carboniferous system of Scotland, at Burdie House near Edinburgh, and of some value in establishing a geological identity between the isolated coal measures of Staffordshire, and the carboniferous rocks in distant parts of Great Britain.

A small coal-field near Shrewsbury, in other respects of no special interest, derives some importance from the presence in it of a band of limestone of a very pale blue colour, which lies between the upper seams of coal. This limestone varies in thickness from three to eight feet, and has been determined by the nature of the fossils it contains to be of freshwater origin. The same bed, similarly characterised, has since been found in other coal districts

at a considerable distance, being observable near Manchester, where it is called the "Ardwick limestone," and also near Coventry, and in various parts of the carboniferous district of Warwickshire.

There is another coal-field in Flintshire, which is probably continued under the New red sandstone to join the Lancashire carboniferous series. The presence of mountain limestone which crops out on the western edge of this basin, shows how limited is the tract in which that important member of the system is absent. The Flintshire coal-field measures about forty miles in length, but its breadth is not more than three or four miles. The mountain limestone forms the base of the series, and is succeeded by beds of shale, gritstone, and chert, above which the coal measures appear. The main coal is eight or nine feet thick, and the other seams vary from two to four, or six feet: some of those near the surface have been much worked.

All these comparatively small deposits of the carboniferous period, have been more or less affected by subterraneous disturbances, and are crowded with faults, their presence at the surface being, in a large number of cases, entirely the consequence of such movements. These faults are often of very considerable extent, and their direction may be traced on a geological map by the straight lines of demarcation between the carboniferous and the newer strata. Other effects of igneous action, exhibited in the occurrence of large quantities of basalt (as for instance in the Clee Hills, &c.) are occasionally seen; and there is quite sufficient evidence that during, and immediately succeeding, the deposit of the carboniferous system, the district which now forms the middle of England was exposed to the action both of denuding and disturbing forces to a great extent.

CHAPTER XII.

THE CARBONIFEROUS SYSTEM OF THE BRITISH ISLES.

3. NORTH OF ENGLAND.

CARBONIFEROUS SYSTEM.—NORTH OF ENGLAND.*

The base of the carboniferous system in the north of England is only seen in two localities, viz., in the extreme northern part of the formation, where the Cheviot Hills pierce through and bring to the surface the Old red sandstone, and in the north-west, where, in a manner nearly analogous, the mountain limestone passes round the flanks of the Cumberland Hills, and a sequence may be observed in sections reaching to the igneous and altered rocks which form the mineral axis of that range. In other cases, as represented in the diagram, the lower carboniferous beds are found either resting quite unconformably upon the older rocks beneath, or the elevatory forces have not been sufficient to pierce through the

* 3. Millstone grit and coal.
2. Limestone, coal shale, and sandstone. Yoredale rocks.
1. Scar limestone with caverns.

mass of superincumbent strata, and the geological sequence is imperfect.

Although the carboniferous deposits are continuous, or nearly so, throughout the northern counties of England, the whole group may be conveniently subdivided into three parts, each admitting of separate consideration, and each distinguished from the others in the order and relative value of the beds of coal which form the most important member of the system in an economical point of view. These three are, (1) the Yorkshire, Derbyshire, and Nottinghamshire series; (2) the Lancashire coal-field; and (3) the Durham and Newcastle coal-fields.

(1.) The carboniferous system as exhibited in Yorkshire and Derbyshire, consists of a magnificent development of mountain limestone, to whose presence the picturesque scenery of those counties is due, and the limestone is partly overlaid on the east, west, and north, by the millstone grit, the whole being surmounted by the coal measures. The lower part of the millstone grit, however, is sometimes represented by a series of laminated and often bituminous shales, which rest immediately on the limestone and contain some bands of ironstone, and a few thin black limestones; while the upper part consists of several hundred feet of pebbly grits and other sandstones, alternating with thin bad coal. The productive and valuable coal seams, which have been much worked, and of which there is a considerable number, occupy their usual position at the top of the series, and consist of beds varying from two to five feet in thickness: the coal is bituminous, like that obtained from Newcastle, but is of inferior quality.

Further north, and in the north-western part of Yorkshire, the mountain limestone becomes a still more impor-

tant and prominent member of the carboniferous series, and is capable of local subdivisions. In the district from which the section at the commencement of this chapter was taken, it is subdivided into two groups, whose total thickness is about eighteen hundred feet. Of these two, the lower, the *Scar limestone* (1), forms bold bluff precipices, and is pierced in many places by large natural caverns; and both here and in the upper strata, [the Yoredale rocks (2),] the limestone is remarkably different from the contemporaneous beds in the south, containing thin seams of coal, sometimes worked, and divided into several beds by partitions of grit and shale. The Yoredale rocks thus contain at least five distinct beds of limestone, alternating with freestones, flagstones, &c., and attaining a thickness of as much as a thousand feet. In the north-west of England, where the mountain limestone is developed in the same manner, the upper beds of the series, the millstone grit and the true coal measures, are scantily exhibited; but in the north-east, as in Northumberland, the Scar limestone is much broken by the interposition of pebbly grits, shales, and coal seams, which entirely change the character of the formation. It is chiefly on the middle and eastern side of the deposit, between Derby and Leeds, that the coal is met with abundantly, but beyond the latter town, as far as Darlington, where the Newcastle district commences, there is a distance of at least fifty miles, occupied chiefly by the millstone grit, and presenting no appearance of the upper beds.

(2.) The carboniferous deposit, generally known as the *Lancashire Coal-field*, occupies the chief part of the southern division of the county of Lancaster, and extends into portions of the adjoining counties, ranging about forty-six miles from north to south, and about forty miles from

west-south-west to east-south-east. It commences with the lower millstone grit, and extends upwards to the Ardwick limestone, generally considered the highest portion of the coal-bearing series in England.

This carboniferous deposit rests on the mountain limestone, which contains no coal, and which here forms the base of the whole system, reposing on the Old red sandstone between Brough in Westmoreland and Bramton in Cumberland, and connecting the Lancashire with the Newcastle coal-field.

The strata immediately overlying the mountain limestone, consist, as usual, of a series of sandy beds containing bands of argillaceous matter and coal, and pass (on the flanks of the Pennine chain) into the lower coal seams, which are, indeed, of no great thickness, but are valuable from their quality and position, and remarkable for the shales associated with them, which contain numerous fossil shells of the genera Pecten, Posidonia, Goniatites, and others. Next to these lower and thin seams there are others much thicker (as at Worsley, Wigan, &c.), forming, in fact, the richest portion of the field. At the upper part of all is the Manchester coal-field containing the Ardwick limestone, (an interesting freshwater deposit,) and one or two isolated coal-fields.

The total thickness of the whole varies greatly in different localities, and in some parts the number of seams of coal, each exceeding a foot in thickness, amounts to seventy-five, forming altogether one hundred and fifty feet of coal without taking into account the smaller seams.* There have been found in some parts of the formation in the neighbourhood of Manchester, numerous trunks of large

* Report of the Twelfth Meeting of the British Association, Transactions of the Sections, p. 50.

trees standing upright on the coal seams, and the almost invariable occurrence of stiff clay, forming a floor on which the coal rests, has been supposed to prove, that vegetable matter formerly grew upon the spot where the coal is now found, although the great and sudden alterations in the thickness of the seams show, that the surface was exposed to frequent changes of level. Some very considerable faults are known in the coal-field, the principal one being so extensive as to carry the coal one thousand yards below its former level.

(3.) *The Newcastle coal-field.* I shall have occasion to allude to this coal-field more in detail, when speaking of its economic importance in a future chapter. The seams of coal rest upon the millstone grit and mountain limestone, and alternate, as usual, with shale and sandstone, but the ironstone, so abundant in the more southern coal-fields, is comparatively rare and unimportant. About thirty seams of coal are known, but their total thickness does not exceed ten yards, although each of the beds worked averages from six to seven feet. The coal is extremely bituminous, and probably the best in the world for domestic purposes. It supplies the whole of the east and south of England and the city of London, and a large quantity is also exported to foreign countries. The carboniferous strata are covered up by the magnesian limestone on the east, and have been worked to some extent by shafts passing through the beds of that formation.

The Newcastle, like the other coal-fields, is much disturbed by faults and dykes, insomuch that there is scarcely a colliery in which several are not met with, throwing the strata out of their original position, and placing them at different levels. The most important of these, and indeed the most remarkable basaltic dyke in England, commences

in the southern part of the Newcastle coal-field, near Bishop's Auckland, in Durham, and, running in a direction a little south of east, crosses the Tees, and cuts through the secondary rocks of Yorkshire, being traceable for a distance of nearly sixty miles in a straight line. It then communicates by a cross dyke with a third dyke almost equally extensive, and parallel to the first, extending from Brampton to near Alnwick, in Northumberland, and, like the others, passing through all the rocks of the carboniferous system.

4. Scotch Carboniferous System.

The carboniferous formations, cut off by the Old red sandstone, and by the still older rocks of the Lammermuir hills, are again repeated in the basin of the Clyde, the coal measures covering up at intervals all the lower tracts between the Frith of Forth and the western coast of Scotland, and extending, though not continuously, for about a hundred miles in length, with a breadth of thirty or forty miles.

In this district the Old red sandstone constitutes the general base of the coal-strata, and the transition from the one formation to the other is gradual and almost imperceptible, the upper beds of the Old red sandstone being overlaid by sandstones of similar character and great thickness, which contain occasionally coal plants and even thin seams of coal, and replace the mountain limestone as the lowest carboniferous deposit. Next to the sandstones there is a group composed of a number of thin bands of limestone, alternating with sandstone and shale, and containing also some valueless beds of coal, and this group is surmounted by well-defined thick limestone strata, upon which the productive coal measures rest. The latter, both

in the condition of the coal and the nature of the associated bands of shale and ironstone, present close analogies with the corresponding formations in England.

The number of beds of which the coal measures in Scotland are made up is not a little remarkable, being said to amount to 337, of which not less than eighty-four are seams of coal. The total thickness of the group is very great, and is estimated at about five thousand feet, and the valley of the Clyde has of late years risen into great manufacturing importance, rivalling with success the older establishments in South Wales and Staffordshire in the manufacture of iron, in consequence of the richness of the iron ore in Scotland, and the method introduced there of economising fuel by the use of the hot blast in the process of smelting; these advantages much more than counterbalancing the greater expense incurred in working the coal. Occupying a position in the carboniferous series below the coal measures and millstone grit, and among the argillaceous and bituminous shales of the lower part of the formation in Scotland, a very interesting bed has been described by Dr. Hibbert,* under the name of the "Burdie-house limestone." The limestone itself, and the beds associated with it to some extent, both above and below, are apparently of freshwater origin, and indicate the former existence of an extensive lake, which, during the period of deposit of the upper Palæozoic rocks of Scotland, covered the tract of country on which Edinburgh and its environs now stand. The limestone is as much as twenty-seven feet in thickness, and crops out at Burdiehouse; but there is no evidence of the deposit being continuous. Many fossils, both animal and vegetable, have been found in it, some of which, especially the former,

* Trans. Roy. Soc. of Edinb., vol. xiii. p. 169.

possess very considerable interest, and will be described in a subsequent chapter.

5. Irish Carboniferous System.

The carboniferous deposits in Ireland occupy a more prominent position in the Geology of that country than they do either in England or Scotland, as they may be traced in one direction for nearly a hundred and fifty miles, with a breadth of as much as a hundred and twenty, occupying not less than ten thousand square miles of territory. The whole tract may be conveniently separated into three districts, distinguished from one another chiefly by intermediate masses of the Old red sandstone, which pierces through the newer rocks, and is extensively developed on the edges of each of the coal-fields, forming, wherever it appears, the base of the carboniferous system.

The general sequence of the rocks of this period in Ireland resembles that which has been already described in speaking of the coal-fields of Wales and the middle of England. The mountain limestone occupies an important place, and consists of two great bands of limestone, with a considerable thickness of shale and argillaceous limestone and sandstone interposed, which are known by the name of *calp* or calp slate.* It is chiefly, however, in the northern and middle districts that the calp is found, and it gradually thins out towards the south. Beneath the lower limestone another series of schistose beds (the *carboniferous slate*) occurs, and this rests on a series of sandstone beds, often alternating with shale, and occasionally with limestone, these lower beds resting conformably on the Old red sandstone. The 'carboniferous slate' of the south of Ireland

* Report of the 12th Meeting of the Brit. Assoc., Transactions of the Sections, p. 52.

differs considerably in lithological character from that of the middle and northern regions, but, from the evidence of fossils, must be looked on as contemporaneous.

Overlying the true mountain limestone is the millstone grit, which, as well as the limestone, is extensively distributed, and is totally devoid of any trace of carbonaceous matter. The upper beds are the coal measures, and are chiefly found in four districts, two of them in the north—the one in Connaught, and the other in Ulster—producing bituminous coal, like that of Lancashire. The other two, those of Leinster and Munster, contain the non-bituminous variety, called anthracite, which is also found in the western part of the South Welsh coal-field.

The South Munster coal-field occupies a large area; but the seams of coal hitherto met with are comparatively few in number, and of little value, nor is it probable that many more will be found, as the beds are for the most part sufficiently exposed, both naturally by rivers and ravines, and artificially by roads. The carboniferous limestone, which is the lowest bed, is here succeeded by shale, and afterwards by sandstones and grits, which are more or less argillaceous, and occasionally micaceous, forming hard compact rocks with a fine grain. The coal is anthracitic, and occurs either in the state of pure anthracite, or in thin slaty layers associated with black carbonaceous shale.

The Leinster coal-field is also very extensive, and is divided by undulations of the mountain limestone into three districts, of which the Killenaule is the principal. This district is about six miles broad in the widest part, and eighteen miles in length, and the culm has been extracted from several localities. The best seam varies from fifteen to eighteen inches in thickness, and it has been worked along the northern outcrop pretty extensively, but

without system. In the Lisnamrock and the Coalbrook seams the thickness is somewhat greater, and, owing to the nature of the roof and floor, the whole of the coal can be safely extracted. The accompanying rocks consist chiefly of a close and fine-grained gritstone, together with about ten feet of excellent fire clay, and a quantity of bluish grey or black limestone. It is not probable that any of these localities will ever become of great economical importance as coal-fields, but they are exceedingly interesting to Geologists, and the limestone of this period in Ireland is rich in organic remains.

The subjoined vignette represents a view of the town of Newcastle-upon-Tyne. This spot needs only to be mentioned to remind the reader of its great geological and economical importance, as connected with the Carboniferous deposits of the British Isles.

NEWCASTLE-UPON-TYNE.

CHAPTER XIII.

THE CARBONIFEROUS SYSTEM IN FOREIGN COUNTRIES.

Rocks contemporaneous with those of the English carboniferous system, and containing amongst their number some carbonaceous deposits, have been discovered in many parts of the world besides our own islands, and more particularly in northern and eastern Europe, in central France, and in Spain. Similar deposits have also been supposed to exist on the coast of Syria, in the basin of the Indus, in the Island of Batavia, on the eastern coast of China, in the Australian Archipelago, and in many parts of North America. Some of these localities are only known to contain carboniferous rocks, because coal, identified by the fossil vegetable remains associated with it, has been from time to time obtained from them: with regard to such, the mere mention of the fact is all that can be said concerning them; and, indeed, the few remarks my limits will allow me to offer will have reference to the better known of the foreign carboniferous strata, namely, those of Westphalia, Belgium, Russia, and France, and the formations of the same date in the western states of North America.

In a former chapter the uppermost of the Devonian strata in Westphalia were described as beds of sandstone and shale, passing into calcareous shales, containing fossil remains of the carboniferous type. These therefore are

assumed as the base of the carboniferous system. They are immediately succeeded by a group of black imperfect limestones and siliceous schists, (*Kiesel-schiefer* of the Germans,) considerably expanded and traceable for some distance, and looked upon by Messrs. Sedgwick and Murchison* as the undoubted equivalents of the English mountain limestone, the underlying beds representing the shales occasionally met with in England when the sequence to the older rocks is complete.

The black limestone is extremely carbonaceous, argillaceous, and fetid, and it corresponds so entirely in mineral character with the culm limestone of Devonshire, that the description of the one rock might almost serve for the other, not merely as regards its general appearance and lithological character, but also because the organic remains, —the Goniatites and Posidoniæ,—with which the rocks in Devonshire are loaded, are in Westphalia also by far the most abundant fossils of the deposit. On the Continent, however, the culm limestone passes upwards into another limestone of a lighter colour, and this bed contains all the most characteristic fossils of the true English mountain limestone.

Generally speaking the flinty slate (Kiesel-schiefer) is overlaid by, or alternates with, beds of shale, and is seen exposed in the quarries, resting on the black limestone, and passing upwards into the lower beds of the coal measures, which are occasionally very much expanded, and form hills several hundred feet high. These beds are composed of dark-coloured pyritous shales which have been used in the manufacture of alum, and the sequence from them to the upper and productive coal measures is unbroken. The coal occurs amongst beds of

* Geol. Trans. 2nd Ser. vol. vi. p. 232.

sandstone and shale, with courses of ironstone, and is not to be distinguished in its lithological characters from the ordinary coal strata in our own country.

The carboniferous series in Belgium is not easily made out, nor can it be understood without considerable previous knowledge of the relations of the strata as they are exhibited in less obscure and less disturbed districts. The difficulties that stand in the way chiefly arise out of the enormous derangements of the strata, which are not only violently contorted, but often elevated through an angle greater than a right angle, and are thus actually inverted,* so that the basin-shaped depressions in which the coal occurs are twisted out of place, and the whole Geology of the district apparently thrown into confusion. The only method of escaping from the difficulties thus introduced is to obtain horizontal sections, or ground plans of the various rocks in the district. In this way, by actually walking upon the edges of the strata, they may often be recognised as the same, in cases where vertical sections would appear to prove, that the newer beds were overlaid by a long series of more ancient

* The simplest method of acquiring a true notion of the singular appearance and puzzling nature of these inversions of strata, is to consider such a case as that represented in the subjoined diagram, where a series of strata, originally horizontal,

COAL BASINS OF BELGIUM. OBLIQUE BASINS.

have been first disturbed and elevated by an igneous rock, and afterwards again by another eruption; the second disturbance acting chiefly between the two points of eruption and squeezing the beds laterally and with great violence. As a consequence of this pressure the shales and other strata have been contorted into undulations, and puckered up just as a number of pieces of cloth are found to be if pressed vertically and at the same time squeezed laterally. The effect of this is represented in the diagram, and the axis is more or less inclined, according to the amount of disturbance.

ones. It is, however, rarely that such extreme disturbance and alteration of position has taken place, and the few cases in which it is possible may soon be recognised, so that the value of vertical sections is not for this reason diminished, nor should the confidence placed in them be shaken. They still remain most valuable means of communicating geological information, and it is no ground of objection to their use that the accompanying map, which they always require, must occasionally be in such detail as to become a ground plan.

When examined and carefully investigated with such horizontal sections as I have just described, the Belgian coal strata are found to arrange themselves in nearly the same order as those of Westphalia, the beds of the Devonian period passing into fossiliferous beds of limestone by a yellowish sandstone, and this limestone, the true equivalent of the mountain limestone, being again succeeded by the gritstones, which there, as in England, underlie the true coal measures.

Passing on now to the north and north-east of Europe, we shall find the various rocks of the carboniferous system occupying a most important position among the Palæozoic formations of Russia, and covering an area of very great extent; the coal-bearing portion of one district alone being calculated at not less than ten thousand square miles. In Russia, the lower carboniferous beds consist of incoherent sandstone, alternating with a bituminous shale, which sometimes contains thin bands of impure coal and impressions of plants; the whole being surmounted by various beds of limestone, which form the central group of the carboniferous system. Of these beds, the lowest is usually of a dark colour, as in other parts of Europe; but the middle, and most extensive, differs entirely from any contemporaneous

rock, being of a milk-white colour resembling chalk, and loaded with flints. It is also of considerable thickness, and extremely fossiliferous, and alternates with beds of compact yellow magnesian limestone, and bands of red or greenish shale or marl, while associated with it there are splendid masses of white gypsum and thin bands of limestone interstratified. The third, or upper division of the series, is scarcely less remarkable than the central, being almost entirely made up of myriads of fossil bodies (called *Fusulina*), resembling grains of wheat, and forming a limestone which is of considerable thickness, and appears in the lofty cliffs which occupy the banks of the Volga, and also in the coal region between the rivers Dnieper and Don.

In Northern Russia, and in the upper beds of the Volga, the central limestone of the carboniferous system is totally devoid of coal, which is found in shales and sandstones, interstratified with thin courses of limestone in the lower part of the series, and in this respect exhibits a resemblance to the lower beds of the mountain limestone in Yorkshire. The total thickness of the coal-bearing strata is about eight hundred feet, and the coal, where it has been worked, is of fair average quality, and some of it exceedingly good; but the number of workable seams at present known does not exceed seven.

In the South of Russia, on the other hand, the central beds of the carboniferous system are occasionally productive of good bituminous as well as anthracitic coal, offering, in some points, very striking analogies in mineral condition to the great South Welsh Basin. The northern beds are nearly horizontal, but the coal-field in the south appears to have been disturbed, and to have been broken up by faults; resembling, indeed, in this respect, almost all the other contemporaneous formations.

Among the few districts in Europe, south of our own island, in which the carboniferous system is fully exhibited, and contains beds of workable coal, it is worth while to allude to that of St. Etienne in central France, as at once the best known and the most interesting, and the one of greatest importance for its economical value.

This little coal-field is contained in a trough between the valleys of the Loire and the Rhone. Its length is about twenty-five miles, and its greatest breadth not so much as one mile; the beds which fill this elongated basin rest on granite to the west and north-west, on gneiss to the south and south-west, and elsewhere on mica and mica schist; the greater part of the substance of the deposit being derived from the degradation of the same crystalline and metamorphic rocks, out of which the hollow which contains them was originally scooped. The general arrangement of the mineral masses is this:—they form a series of micaceous sandstones, based upon a coarse conglomerate, the upper beds alternating with shales, and the coal occurring in a thin-bedded micaceous grit, in which, as well as in the shales, vegetable markings of all kinds are sufficiently abundant.

The coal of St. Etienne is occasionally accompanied by an ore of iron, similar to that found in Staffordshire and Wales, and this ore has been much and very advantageously worked. In one instance a curious phenomenon is observed. A bed of coal which underlies one of the bands of ironstone has, by the action of subterraneous fire, undergone fusion, and become changed to coke, native sulphur and crystals of sulphate of lime having been separated apparently by the process of sublimation.

It occasionally happens in this coal-field, that the fossil remains of the trunks of trees are exhibited in a position

nearly vertical; and in one mine in particular (worked as a quarry in the open air), it almost appears as if an actual forest of ancient trees had been petrified *in situ*. But in this case, the beds of sandstone and shale through which the trees pass remain nearly horizontal, and the whole deposit has been very little disturbed, the undulations of the surface of the underlying crystalline rocks being evenly covered by the carboniferous sandstone, while no faults occur to break or disturb the continuity of the beds.

The position of these broken trunks of trees remains unaccounted for, but the beds have doubtless been deposited with great rapidity. Although so little disturbed, they are not by any means uniformly horizontal, but are frequently inclined at an angle of ten or twenty degrees, especially near the edges of the basin.

In the south of France, a multitude of small coal basins occur, presenting analogies both in form and structure to this of St. Etienne, which may be considered as the type of the whole class; and the simplicity and regularity of appearance which they exhibit, the absence of disturbances subsequent to their deposition, and their complete isolation from the underlying and overlying formations, contrast singularly with the violent contortions and complicated disturbances to which the beds of the same age in Belgium have been exposed.

Without dwelling upon the details of the various smaller and less important fragments of the great carboniferous system throughout the world, I must pass on now to say a few words on some of those tracts in North America, where the Geological formations would appear to be on a scale of grandeur corresponding to that of the other physical features of the great continent on which they are developed.

There appear to be in North America several extensive tracts, containing rich coal-bearing strata of the age of the carboniferous deposits of England. Some of them abound with vegetable remains of species identical with those characterising the English beds, but the condition of the coal is almost invariably anthracitic.

According to Professor Hitchcock,* nearly the whole of the basin of the Mississippi, from the Alleghanies to the Rocky Mountains—a space equal in area to two-thirds of the continent of Europe—is covered by a series of deposits, of which the upper portion represents the carboniferous system, and the lower passes downwards into the Middle and Lower Palæozoic systems, exhibiting an enormous total thickness, and reposing on non-fossiliferous but stratified rocks. It is not to be supposed that the coal is distributed over the whole of this district; but it is found in many places greatly expanded, and usually occupying basins in the upper part of the carboniferous series, as in Wales and Russia.

Pennsylvania and the adjacent States appear to contain the most valuable and extensive of the numerous beds of North American anthracitic coal, and this district has been carefully surveyed under the direction of Professor Rogers. A very brief sketch of the result of the survey, so far as regards the carboniferous series, will perhaps give some idea of the nature and extent of the American rocks of the newer Palæozoic period.

The carboniferous series of Pennsylvania is stated† to extend for about two hundred miles in length, and to be based upon massive sandstones, conglomerates, and shales, overlying a bed of fossiliferous limestone. Resting upon

* Ed. Phil. Journ. vol. xlvi. p. 75.

† Proceedings of Geol. Soc. of London, vol. iii. p. 708.

this group, which is of great and uniform thickness, there is a deposit of red shale, which varies in thickness from three thousand to less than one hundred feet, and is supposed to thin out and disappear to the south-west; and this is partly overlaid and partly replaced by a hard coarse conglomerate, very thin towards the north-west, but rapidly swelling out, and becoming from eight to twelve hundred feet thick towards the south-east.

None of these formations contain profitable coal, although the remains of plants are found in them, and a few seams about a foot thick occur in the red shales. The coal measures themselves form the uppermost part of the series, and consist of micaceous sandstones, arenaceous, argillaceous, and carbonaceous shales, and valuable beds of limestone, together with about ten seams of coal, having an aggregate mass of fifty feet. The northern anthracitic region, however, contains coal seams, which are much more valuable though not so extensive; and here the coal measures consist of seven hundred feet of sandstones and shale, and contain fourteen or fifteen beds of coal whose total thickness is seventy or eighty feet. The most important bed is as much as thirty feet in vertical dimensions, including the interstratified shale, but only eighteen feet of it are generally worked. The quantity of limestone in this district appears to be very small, compared with the extent of the deposit and the predominance of calcareous bands in Europe.

In Nova Scotia there is found a development of carboniferous strata which resembles lithologically the English coal measures, being composed of white and brown sandstones and bituminous shales, alternating with coal, and associated with ironstone and clay. These beds are not interrupted by faults, but possess a thickness of more

than two thousand feet, and range for nearly two miles along the coast. They are remarkable for containing numerous trunks of trees, varying in height from six to twenty feet, which rise from beds of coal or shale, and pass through different strata of shale or sandstone, but never of coal, and are all broken off abruptly at the top. The trees occur at different levels, and over a surface which extends nearly as much as three miles from north to south, and more than twice that distance from east to west. The number of seams of coal is about nineteen, and the greatest thickness of any one does not exceed four feet. They are usually inclined at an angle of about 24° to the S. S. W., but the trees are always at right angles to the plane of stratification.*

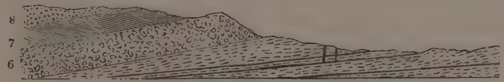
The subjoined vignette represents the interesting scenery of that part of the Meuse, near Namur, where the river makes a sudden turn to the east, through a picturesque gorge in the carboniferous limestone.

* Proceedings of Geol. Soc. vol. iv. p. 176.

ROCKS NEAR NAMUR.

CHAPTER XIV.

THE LOWER NEW RED SANDSTONE AND MAGNESIAN LIMESTONE.



MAGNESIAN LIMESTONE.—NORTH OF ENGLAND.*

A few words of explanation are necessary—at all events to the Geological reader—in including within the same group of strata the rocks of the Carboniferous system, and a portion of that series which has hitherto been considered in England to belong to the period of the New Red Sandstone. In the classification of rocks which I have ventured to adopt, the Lower new red sandstone and the Magnesian limestone, are, it will be seen, not only ranked as the uppermost members of the Palæozoic period, but are completely identified with the carboniferous system.

This view, however, of the subdivision of the New Red Sandstone formation is not now promulgated for the first time:—Professor Sedgwick proposed nearly twenty years ago, that the formation in question should be

* 8. Upper new red sandstone.
7. Magnesian limestone.
6. Lower new red conglomerate.

considered as made up of two distinct members; and he asserted, that the lower and older beds passed by insensible gradations into the carboniferous system, while the upper beds, lying for the most part unconformably upon the lower ones, constituted a distinct group of strata.*

Since the publication of the paper alluded to, every additional information that has been recorded upon the subject has tended to show more completely the correctness of the view therein advocated; but no one has yet ventured in any general work on Geology to draw the line of demarcation, and class the Lower new red sandstone and the magnesian limestone with carboniferous rocks. It must not be forgotten, however, that Mr. Lyell† has pointed out the analogies existing between the two, and he, as well as Prof. Phillips,‡ has stated, that according to the evidence of fossils, the magnesian limestone approximates much more nearly to the carboniferous rocks than to the overlying beds of the New red sandstone.

But the adoption of the term Palæozoic, and the revision of the older rocks which has lately taken place, offers an opportunity for the introduction of this change in nomenclature which it would be unwise not to take advantage of; and although, probably, so far as English Geology is concerned, the change would hardly be required, it will be seen, in speaking of foreign contemporaneous formations, that the line of separation is there sufficiently well marked to render it absolutely necessary.

The magnesian limestone, and the beds associated with

* Trans. of Geol. Soc. of London, 2d Series, vol. iii. p. 37. This paper of Professor Sedgwick's is the source of almost all the information hitherto communicated on the subject of magnesian limestone of the north of England.

† Elements of Geology, 1st edit. p. 415.

‡ Treatise on Geology, vol. i. p. 189.

it, rest immediately on the upper strata of the carboniferous system, and may be traced from Nottingham to the mouth of the Tyne continuously, capping the coal measures but not rising to a high level, except in part of the county of Durham, where they are cut off by the coast line. The rock, being for the most part easily disintegrated, has suffered much from denudation, and several outliers, or portions of the strata completely isolated from the principal mass, are seen from point to point beyond the edge of the formation.

The subdivisions of the two series, as observed by Professor Sedgwick in the north of England, are thus expressed in descending order. The total thickness exceeds eight hundred feet.

Magnesian Limestone Series.	Grey thin-bedded limestone. Red marl and Gypsum. Magnesian Limestone, or *Zechstein*, a deposit attaining a thickness of 500 feet, often earthy, but sometimes hard and crystalline.
Lower New Red Series.	Marly beds, associated with thin bands of compact and shelly limestone. Lower new red sandstone, or *Rothe-todte-liegende.*

As the development of these rocks is chiefly confined to the northern part of our island where the Lower new red sandstone, capped by the magnesian limestone, overlaps the eastern edge of the coal measures, it will be convenient, in the first place, to describe the different parts of the formation as they there present themselves, and afterwards consider the contemporaneous strata in the west of England.

The lowest bed of the whole group is called from its lithological character and relative geological position "the Lower new red sandstone;" but it might very fairly be associated with the upper coal measures, for it contains

numerous remains of extinct vegetables not to be distinguished from species found throughout the carboniferous system. It differs somewhat, however, from the coal-grits in mineral composition, being more discoloured with oxide of iron, besides being chiefly made up of a conglomerate in which quartz and decomposed granite abound. This conglomerate, although in its lower portion exceedingly coarse, passes upwards into a fine-grained sandstone, and so by finer sands mixed with marl shows a gradual transition to the upper and marly beds. Beds of freestone are sometimes, but rarely, found alternating with the fine sands and clays of this division; and the mass is altogether very irregular both in thickness and extent, appearing to have presented an uneven surface at the commencement of the deposit of the more recent magnesian limestones, and in some places to have undergone considerable degradation before those beds were superimposed. The irregularity thus described as affecting the lower strata must have been owing, in all probability, to subterranean movements disturbing the bed of the ocean during the period of their deposition; but fossils are, notwithstanding this, sufficiently abundant, and amongst them are the remains of fish, by which the formation is identified with certain bituminous schists on the Continent. The marls associated with the fossiliferous bands in the county of Durham, are also themselves sometimes bituminous, and traces of bitumen occur in thin-bedded compact limestones of the same geological period.

The deposit of magnesian limestone which comes next in order, occupies by far the greater part of the escarpment overhanging the coal measures. It is extremely complicated in its structure, presenting more varieties in the arrangement of its subordinate parts than

any newer formation. Considered, however, generally, the lower part is usually of an open arenaceous texture, and of a red colour, being made up of a congeries of small crystals coated with oxide of iron. The crystals, loosely thrown together, as it were, in the lower beds, occasionally become more closely packed and of a paler colour, and a little higher in the series form a tolerably compact rock, and sometimes a stone of such close grain as to be much used for troughs and cisterns.* This condition of the rock has been supposed, with great appearance of probability, to be owing to the action of heat subsequent to the deposition of the calcareous matter, magnesian vapours having been forced through the rock (originally, perhaps, a simple carbonate of lime,) by means of volcanic agency, and a process of crystallisation thus superinduced. The magnesian limestone in this state is called *Dolomite*, and the crystalline or semi-crystalline structure of the mineral is usually predominant, although in some quarries a compact† form of it is seen, associated with thin beds of crystalline rock of loose texture, of the same kind as those described above. The compact dolomite has a flat conchoidal fracture, and is translucent at the edges; but it is very irregular in structure, and passes by insensible gradations into other varieties.

The magnesian limestone occasionally puts on other and very different forms: at one time, for instance, we find it made up of laminæ parallel to the plane of stratification;

* In this part of the series occur the more valuable building stones of the magnesian limestone; and the kinds which are most durable, and are selected for the finest work, are always those in which the crystalline action has been most fully perfected.

† A mineral is said to be compact when the separate particles of which it is made up are not discernible, but when, also, it cannot be cleaved or divided into regular or parallel portions. A mineral is said to be possessed of crystalline structure when it can be so divided.

at another, of earthy masses, which are sometimes hard and regularly bedded, and sometimes unstratified; but all these I must pass by with a mere mention, in order that I may have space to say a few words on a still more striking and interesting appearance:—that in which it exhibits a remarkable concretionary structure.

This peculiarity of structure is sometimes so predominant as to have obliterated the lines of deposition, and a section of the rock then exhibits a mass of crystalline, compact, cellular, and earthy materials rudely blended together, and passing into each other without order or arrangement.

But in all this apparent confusion the minute grains which enter into the composition of the rock are occasionally well defined and of spheroidal shape. The mass, in such a case, appears oolitic, (or made up of little egg-shaped particles,) and there are several localities in the southern part of Yorkshire where oolitic magnesian limestone is worked as a free-stone, and resembles not a little the building stone obtained near Bath from the Secondary rocks. Like this latter stone it cuts readily in the quarry, and hardens on exposure to the atmosphere; but, on examination, the grains are found to be less uniform in size, to possess a glimmering lustre, and to be hollow and made up of concentric laminæ.

The most remarkable instances of concretionary structure that have yet been described are seen on some parts of the coast of Durham, where the magnesian limestone forms bold cliffs, which appear as if made up of an irregular pile of cannon balls. In this case, however, the carbonate of magnesia forms but a subordinate part of the rock, the concretions themselves consisting of carbonate of lime; and it would seem that, during the process by which the concretionary structure was effected, the magnesia was almost

entirely separated, and left in the form of dolomitic or magnesian earth.

The curious spheroidal masses above alluded to are found associated with the laminated variety of magnesian limestone; and, on separating the beds, the laminæ are often seen not to be continuous, but made up of circular plates, running into one another. In this case the discoid forms of the laminæ indicate a tendency to aggregation about different centres, even when, owing to some cause, the operation could not develope itself in a vertical direction.

At the planes of separation, however, between two of these laminated beds, the concretions are more perfect, and approach the spherical form; the spheroidal masses impress both the upper and lower surfaces of the beds with which they are in contact; and the rock exhibits at one and the same time an earthy, a crystalline, a laminated, and a spheroidal structure. It is clear, therefore, that the concretionary form has been superinduced by some internal movement of the particles after their deposition.

When the concretions are more perfect they are sometimes grouped into beautiful and regular clusters, or, by mutually penetrating each other, produce a number of grotesque forms, and occasionally a kind of honeycombed appearance, in which the small cells are arranged in horizontal lines, but still in concentric circles. These, as well as the former peculiarities of structure, require for their explanation the agency of some causes acting upon an extended scale after the deposition of the beds, by which their original structure was more or less nearly obliterated, and sometimes so entirely destroyed as to produce the singular appearance already described in the cliffs near Durham.

The great rarity of fossils in the magnesian limestone is another fact worthy of notice, and one with difficulty to be explained, without supposing that some changes have taken place which have effected the destruction of its organic remains; because, wherever the presence of magnesia is not observable, and circumstances seem to have been more favourable for the preservation of fossils, they are found in vast abundance. It is probable, then, that corals, molluscous animals, and fish, existed in the seas, and were extremely numerous during the time when the beds were being deposited, but that their remains are absent, partly from the matrix not being favourable for their preservation, but chiefly because those fragments which did form part of the strata have been since destroyed by chemical and mechanical changes which have taken place within the substance of the rock.

The beds which overlie the magnesian limestone consist of a series of gypseous marls of variable thickness, and sometimes occupy the base of a low escarpment, formed by a grey thin bedded limestone, (the highest bed of the dolomitic series,) which dips into the plain of the New red sandstone. The thinness of the uppermost beds is characteristic, and they often pass into mere laminæ, with plates of marl interposed between them. Organic remains are not commonly found, and when they do appear they are extremely obscure.

On the whole, we may observe of this deposit in the north of England, that it forms a natural and well-defined group, passing by gradual transition into the coal measures, and proved to belong to the same geological sequence by the consistent evidence of sections. The evidence of fossils is still more decided, and both in England and on the continent the organic remains, both of animals and

vegetables, indicate a far closer approximation to the carboniferous system than to the upper beds of the New red sandstone formation.

The magnesian character also of a great part of the whole series is consistent throughout Europe in rocks of the newest Palæozoic period, although, as I have already had occasion to mention, magnesian limestone of the true carboniferous period occurs in Russia, and is also met with in some of the contemporaneous beds developed in Derbyshire.

Turning now to the magnesian limestone as exhibited in the south of England, we shall find the carboniferous series of Bristol surmounted by a Dolomitic conglomerate, made up of angular or slightly worn fragments of mountain limestone, cemented by a red or yellow magnesian paste.

This deposit fills up the hollows and irregularities of the lower and older rock, and may be seen in the precipitous cliffs on the Avon. It is undoubtedly the representative of the magnesian limestone of the north of England, the Lower new red sandstone being absent; and in the year 1836 a description of several bones of reptiles found in it was communicated to the Geological Society of London by Messrs. Riley and Stutchbury. By means of these fossils the English series has been connected still more decidedly than before with the continental beds, fragments of similar bones having been discovered in the Thuringian bituminous slates, which also contain numerous species of fossil fish common in the magnesian beds of the county of Durham.

According to Mr. Murchison, the Lower new red sandstone overlies the coal-fields of Staffordshire and Shropshire, although it is there exhibited in a somewhat peculiar form, and differs considerably in lithological character

from its equivalent in other places. Now, as at Bristol, the dolomitic conglomerate, which represents the magnesian limestone, rests immediately and unconformably upon the coal measures, while in the north the whole series is exhibited and widely expanded, being evidently continuous with the carboniferous system, it is not a little interesting to find in the centre of England that particular spot at which the lower beds of the series first make their appearance.

The Lower new red sandstone in the central counties frequently contains concretionary limestone, by means of which it graduates into the coal measures,—a peculiarity which distinguishes this group from the northern beds of the same period, where the arenaceous character is very decided, and the presence of coal plants marks the closeness of the proximity to the true coal sandstones. Throughout the middle of England, wherever the coal measures have been brought to the surface through the unconformable mass of the New red sandstone, the lower beds of calcareous conglomerate belonging to the magnesian limestone are also to be seen, and they are always conformable to the carboniferous system. In the neighbourhood of Bristol and at Exeter, however, this is not the case, and the Dolomitic conglomerates not being there separated from the coal strata by any representative of the Lower new red sandstone, the passage upwards into the Upper new red series is less disturbed, and the line of separation less strongly marked.

CHAPTER XV.

THE PERMIAN SYSTEM AND THE CONTEMPORANEOUS FORMATIONS IN GERMANY AND FRANCE.

The name "Permian system" has lately been proposed by Mr. Murchison to distinguish an extensive group of fossiliferous strata developed in the East of Russia, and intermediate in Geological position between the carboniferous and the Triassic systems, understanding by the latter the upper portion of the New Red Sandstone formation as exhibited on the Continent of Europe.

The Permian system, therefore, exactly corresponds to the Magnesian limestone and Lower new red sandstone of our own country; but it has been judged advisable to give a distinct name to the continental group, and the district in which the rocks are most perfectly exhibited being included in the ancient kingdom of Permia, that name has been selected for reasons similar to those which induced Mr. Murchison, on a former occasion, to apply the term "Silurian formation" to a group typically exhibited in the region of the ancient Siluri.

The Permian district extends for about seven hundred miles from north to south along the western or European flanks of the Ural chain, and for nearly four hundred miles between those mountains and the river Volga. The strata found within this area are described by Mr. Murchison* as lying in an enormous trough of carboniferous

* Proceedings of Geol. Soc. of Lond. vol. iii. p. 724.

limestone, and, although occasionally thrown into anticlinal axes of some length, often traceable for great distances, without any break or interruption of the sequence.

The Permian rocks consist of a great number of distinct strata of very varied lithological character. They are composed, for the most part, of white limestone with gypsum and rock salt, of red and green gritstones with shales and occasionally copper ore, and of magnesian limestones, marlstones, conglomerates, &c. The whole series is highly fossiliferous, and contains the remains of extinct species of animals and vegetables, greatly resembling those of the carboniferous period. In the Russian beds, also, there have been discovered reptilian remains like those of the Bristol magnesian conglomerate, and fish identical with the species from Durham and from Mansfeld in the Thuringian forest.

It is, however, chiefly in Germany, whose Geology has been longer known and is more minutely described, that we must seek for subdivisions of the New Red Sandstone series, to compare with those partially exhibited elsewhere. It has long been found necessary, both in that country and in France, to consider the series as made up of two very distinct parts, the lower and older of which exactly corresponds to the Lower new red sandstone and magnesian limestone of England; while the upper part is totally different in all respects, and being very readily divisible into three groups is now generally known as the Triassic system. It is the rocks which compose the former part of the series that we have now to describe, and the accompanying section will give an idea of the order of superposition, and the names of the different strata.

SECTION ACROSS THE MAGNESIAN LIMESTONE OF GERMANY.

MAGNESIAN LIMESTONE SERIES.	Zechstein.*	7. Letten.	
		6. Stinkstein.	
		5. Rauwacké.	
	Shaly beds.	4. Argillaceous schist.	
		3. Bituminous schist.	*Kupferschiefer.**
		2. Arenaceous schist.	
LOWER NEW RED SERIES.		1. Rothe-todte-liegende.*	

The Lower new red sandstone, or rothe-todte-liegende, as observed in Germany, is perfectly similar, in almost all respects, to the contemporaneous beds in our own country, being made up of coarse conglomerates, alternating with marls and shaly beds, the conglomerates being generally composed of fragments of the neighbouring crystalline rocks, cemented by a fine ferruginous, and sometimes argillaceous sandstone.

In France this deposit is exhibited wrapping round the old rocks which form the central axis of the Vosges. It consists of a coarse incoherent sandstone, generally of a red but sometimes of a bluish-grey colour, alternating with shaly and micaceous marls, the whole formation being extremely variable, both in its mineral character and in

* The derivations of these German names for the strata may be stated as follows:—The upper bed is called *Zech-stein*, (or mine stone,) from its containing a deposit (*Kupfer-schiefer*, or copper slate,) worked to some extent as an ore of copper; and the underlying sandstone has received the name *rothe-todte-liegende*, (red, dead, lier,) because it is of a *red* colour, *underlies* the metalliferous deposit, and is *dead*, or worthless, as far as any metallic produce is concerned. The latter name, rothe-todte-liegende, is occasionally transplanted into English Geological descriptions, and it certainly requires some explanation, at least to the general reader.

the extent of its development. It passes insensibly into the upper beds called the "*gres de Vosges*," or Vosges sandstone, there being no intermediate bed of magnesian limestone. The total absence of fossils renders it impossible to do more than obtain an approximate notion of the true nature of the transition from the lower to the upper beds.

The magnesian limestone series may be traced in the north of France and in Burgundy, but is most fully developed at Mansfeld in the Thuringian forest, in the district of the Hartz, and in Franconia. Throughout the south of France it appears to have no representative, and is most likely altogether absent. When most perfectly expanded, the whole series is divisible into two groups, the lower one for the most part argillaceous, and the upper calcareous, and the series then rests immediately upon the conglomerates of the rothe-todte-liegende.

Of the schistose beds, which form the base of the magnesian limestone series, the lowest is sandy, and forms a kind of transition from the underlying sandstones. It is of no great thickness, and is succeeded by a bituminous band, remarkable for great uniformity both in mineral character and fossil contents, being traceable over a considerable district in Germany, and forming an excellent Geological horizon for an extent of, at least, two hundred and fifty miles. According to M. D'Aubuisson, one tenth part of the mass of this bed consists of bitumen and carbon; and, although not more than a foot in thickness, it contains so considerable a quantity of iron and argentiferous copper pyrites as to be worth working as an ore, whence it has received the well-known name of *Kupferschiefer*, or copper slate.*

* This bituminous schist is also remarkable as containing, in great abundance, the nearly perfect fossil remains of a large number of extinct species of fish. By

The bituminous schist is succeeded by other beds more entirely argillaceous; and these are covered up by a compact limestone, which is the *Zechstein*, properly so called, and which rarely attains a thickness of more than twenty or thirty yards.

The lower bed of the Zechstein is called *Rauwacké*, and consists of a hard but cellular magnesian limestone, abounding in long, irregular, and narrow cavities, which are most numerous when the bed attains a considerable thickness, but are almost obliterated in the thinner and more compact portions.

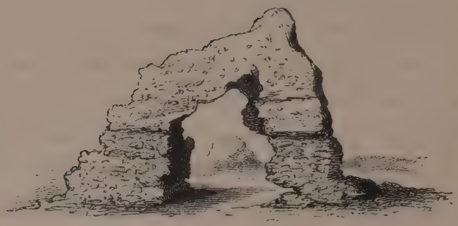
To the Rauwacké succeeds a fetid limestone called *Stinkstein*, which is a compact or granulated rock, of a blackish-brown or greenish colour, and extremely bituminous, giving out an offensive odour when struck or rubbed. Towards the upper part the bed is marly, and passes into a greyish, bluish, or greenish clay, well known under the name of *letten*, and this often contains rolled fragments of dolomite and crystals of gypsum.

In the zechstein and the beds associated with it, there are found occasionally several minerals, and, amongst the rest, white crystallized carbonate of lime, crystallized sulphate of lime or gypsum, quartz, and mica. Both the sulphuret and carbonate of copper, also, occur together with galena in mineral veins traversing the formation.

The very extensive development of magnesian limestones in that particular series of strata deposited shortly after the termination of the carboniferous period, is a peculiarity which it has greatly puzzled Geologists to ac-

means of these, the bed has been identified with the contemporaneous formations in other countries; and as the remains of reptiles have also been discovered, associated with the fragments of fish, the Kupfer-schiefer is thus brought into relation with the Bristol dolomitic conglomerate, as well as with the magnesian limestone of Durham, and the Permian System of Russia.

count for. Except in this one series, limestones, if magnesian, appear to be so in consequence of the action of some subsequent and accidental cause, but here the same peculiarity of chemical composition is common over the whole extent of a continent. Two hypotheses have been suggested to account for the phenomena: the one supposing that the carbonate of magnesia was deposited at the same time as the carbonate of lime, and the other assuming that it was subsequently injected in the form of gaseous vapour. Each hypothesis seems, in some points, to clash with the results of observation; but, as my object is simply to relate the facts, I do not enter into any discussion as to the relative value and probability of the theoretical views deduced from them.



FRAGMENT OF MAGNESIAN LIMESTONE.

Coast of Durham.

CHAPTER XVI.

FOSSIL PLANTS OF THE NEWER PALÆOZOIC PERIOD.

a. NEUROPTERIS FLEXUOSA. Sternberg.
b. SPHENOPTERIS POLYPHYLLA. Foss Fl.
c PECOPTERIS MANTELLI. Brongn.

The vegetable remains, met with in the Devonian and Silurian rocks, are few in number and unimportant, compared with those which so remarkably characterize the rocks of the Carboniferous period; and they are not merely few in number, but their structure, although for the most part very obscure, seems to indicate, either that they had been much longer exposed to the destructive agency of moving

water, or that they belonged to that class of vegetables the species of which inhabit the ocean. It is in the argillaceous and sandy beds of the carboniferous system, that we first meet with any decided proof of the existence of land plants; and these shales and sandstones have been already described as alternating with beds of coal, a peculiar carbonaceous deposit, which is now known to be itself of vegetable origin.

The numerous remains of the leaves and trunks of trees, met with in abundance in the strata denominated "the coal measures," are not, of themselves, sufficient proof of the vegetable origin of coal, although they might render it highly probable, that the source of so considerable an amount of carbon must be looked for in the vegetable kingdom; but the investigations of Mr. Hutton and Mr. A. Burat, and the application of the powers of the microscope to the internal structure of coal, have changed this probability into certainty.*

Although, however, the real nature and origin of coal is now placed beyond a doubt by direct experiment, no assistance has, in this way, been afforded to the Palæontologist, nor is Fossil Botany the more easy to be studied because so large a quantity of altered vegetable matter exists in a fossil state. Indeed, the investigation of

* Mr. Hutton states, (Lond. and Edin. Phil. Mag. 3d Ser. vol. ii. p. 302,) that out of a number of samples of coal from the Newcastle coal-field, taken indiscriminately, more or less of vegetable structure can always be discovered in some of them, and is shown both in the fine distinct reticulation of the original vegetable texture and in the presence of certain cells, filled with a highly volatile and probably bituminous matter. The number and appearance of these cells vary with each variety of the coal, and such varieties sometimes occur within the compass of a single square inch of surface: the cells are supposed by Mr. Hutton to be derived from the reticular texture of the parent plant, rounded and confused by enormous pressure, and their change of appearance in different kinds of coal he considers to be due to original differences in the plants from which they were derived. See also, "Geologie Appliquée, &c. par M. Burat." p. 61.

fossil plants, and the nature of their analogies with species now existing, is beset with obstacles of a peculiar character, and extremely difficult to overcome; and Professor Lindley has observed on this subject,* that "there is, in most cases, an almost total want of that evidence by which a Botanist is guided in his examination of recent plants, and not only the total destruction of fructification and the internal organization of the stem, but also a frequent separation of one part from another, of leaves from branches, of branches from trunks, and if fructification be present, of even it from the parts of the plant on which it grew; so that no man can tell how to collect the fragments that remain into a perfect whole."

Great, however, as these difficulties unquestionably are, they have yielded, at all events in a very considerable degree, to the persevering investigations of a few skilful observers, from whom much has been already learned of the flora of that early period in the history of the globe, when the rocks of the carboniferous system were being deposited. Of such investigators, M. Adolphe Brongniart may well be ranked as the first and the most indefatigable.

The parts of vegetables usually preserved in a fossil state are naturally those of firmest organization: as, for instance, the trunks and branches of trees, the leaves, and in some few cases the fruits; and it appears, from an experiment undertaken by Professor Lindley, that the species whose remains are found in the coal strata are referrible to such families and natural orders, and to such species of them, as are most likely to be preserved unin-

* Fossil Flora, vol. i. Preface, p. vii.

jured for the longest time when exposed to the destructive effects of water.*

Since, therefore, the Palæontologist is able to examine but a small proportion of the plants which in former ages clothed the earth with vegetation, and that he has only imperfect fragments even of these, it becomes the more necessary to learn from the Physiological Botanist all those analogies and differences, by the observation of which even the less characteristic parts of vegetables may be rendered available in determining species, and at the same time he must use the greatest caution in arriving at positive conclusions. And in order that the Geological student may obtain some real notion, however slight, of the condition of vegetation upon the earth during the carboniferous period, it is indispensable that he should be informed of the amount of evidence arising from the examination of fossil plants, and of the nature and value of this evidence; and it is equally clear, that to appreciate the investigations that have been made, he must be acquainted with those principles of Botanical classification, from a consideration of which has been deduced our knowledge of the structure and habits of extinct species of plants. Thus much of Botanical instruction, I consider it necessary, therefore, here to communicate; and I shall endeavour to confine my account strictly to that part of the subject which has immediate relation to Palæontology.

* One hundred and seventy plants were thrown into a vessel containing fresh water, and amongst them were species belonging to all the natural orders of which the flora of the coal measures consists, and also to the other natural orders which it might have been expected should be found associated with them. In the course of two years, one hundred and twenty-one species had disappeared, being entirely decomposed, and of the fifty-six which remained, the most perfect specimens were those of coniferous plants, ferns, palms, lycopodiaceæ, and the like. These, it will presently appear, are precisely those groups to which coal plants are most analogous.

Plants are provided with two distinct sets of organs:—Of these the one set, consisting of the root, the stem, the branches, and the leaves, are immediately concerned in carrying on the function of nutrition, and are styled "the conservative organs;" the other set, consisting of the flower and the fruit, are connected with the function of reproduction, and are, therefore, called "the reproductive organs."

Now, of the former of these organs, the stem and the branches will at once be recognised as forming one group, and the leaves another; and if the internal structure and gradual development of the stem and branches of plants be carefully observed, some will be found, such as peas, and other leguminous vegetables, and the common fruit and forest trees, in the course of whose growth the following series of phenomena occurs:—At first the stem consists of a central pith, surrounded by vessels and cellular tissue, and coated by an epidermis; but as soon as one year's growth is completed, two distinct and complete layers are seen, an inner one of wood, and an outer one of bark. During the next and each successive year, the same thing occurs, and outside the old layers of wood a new one is regularly added, until the plant or tree has attained its full maturity. From this method of growth, by which the new wood is always exterior to the old, the plants so characterised have been called Exogens, and they form a very large proportion of the whole number of species still existing.

On the other hand a similar careful observation of many plants, such as those which grow from bulbs, and of all the numerous varieties of grasses, will exhibit a totally different structure; there being no division of the solid substance of the stem into pith, wood, and bark, but every

fresh addition of matter is carried to the centre of the stem, and as the stem elongates the outer parts become harder and more solid, but the inside remains soft and spongy.* Such plants are called, by Botanists, ENDOGENS, or "those which increase from within," and with the Exogens they include the whole number of flowering species (PHANEROGAMÆ).

Plants which do not flower (CRYPTOGAMÆ) form the natural groups of ferns, mosses, lichens, sea-weeds, fungi, &c., all of which, except the ferns, (in which a few vessels are found) are entirely composed of cellular tissue. There is no such broad and strongly marked distinction amongst them as that just described as existing in flowering plants.

The difference in the internal structure of the stems of flowering plants corresponds with other differences both of the seed and the leaf; for the seeds of Exogenæ are composed of two large opposite lobes, called "*cotyledons*," which are attached to the small rudimentary germ, and when the germ expands represent two imperfect leaves. Endogens, on the other hand, are developed from a spindle-shaped seed, from one extremity of which proceeds the root, and from the other a single cotyledon, inclosing the future stem.

Hence the terms "*Mono-cotyledonous*," and "*Di-cotyledonous*," have been applied respectively to the Endogens and Exogens, while the Cryptogamous, or non-flowering plants, are also distinguished as "*A-cotyledonous*," or those whose seeds germinate without any such lobes for the nourishment of the embryo.

The structure of the stem and seed is therefore some

* The structure of a piece of common cane is sufficiently illustrative of the numerous woody plants of this class found in tropical climates.

guide in the determination of a plant, and one which is useful in fossil remains as well as in the recent specimen; and I may remark here, that being a real and natural ground of classification, not only the general but the minute and even microscopic structure may be depended on as characteristic and distinctive.* Let us next see how far the leaves may be considered as guiding the Botanist to a natural arrangement in his science.

The leaves of plants consist of flattened expansions, made up of a more or less complicated net-work of vessels, the interstices between which are filled up by cellular tissue, the pulpy matter of the vegetable. The green expansions resembling leaves, with which ferns are clothed, differ from true leaves in bearing the fructification of the plant on their surface; they are called *fronds*, and are of more importance to the Palæontologist than any leaves, as they are infinitely more abundant than the latter, and form a tolerably large proportion of the whole number of fossil vegetable remains. The leaves of Monocotyledonous plants differ from those of Dicotyledonous, parallel veins traversing the former, and the complicated interlacing of the vessels marking the latter, while the fronds of ferns are readily distinguished from either of them.

The floral arrangements — the character upon which alone the generic classification of plants depends — are so rarely seen in the fossil state, that they hardly require any detailed notice in this place. Valuable as this method of arrangement is, with regard to existing species, it fails

* I believe this will be found to hold good in all cases; and that, wherever, by studying the structure of an important organ the naturalist obtains an insight into the real arrangements of nature, such a character may be depended on, if employed with knowledge and without prejudice, even to the most minute peculiarities of structure. There is, however, a limit in investigations of this kind beyond which it is not safe to presume.

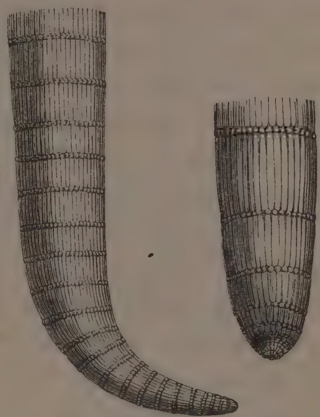
when it is required to apply Botanical science to the determination of fossil specimens in which these parts are usually absent, and where real and important analogies are required to be traced from imperfect data, and the value of apparent differences and departures from typical form is to be accurately weighed and appreciated.

With this general view of the ground-work of a natural Botanical classification, I proceed, now, to the description of a few of those extinct species in which some analogies can be traced to existing vegetables; and commencing with the Cryptogamous plants, I shall first say a few words of the family "*Equisetaceæ*," and afterwards describe the ferns whose leaves or fronds are so abundant in the beds of the Carboniferous period.

Among the most common fossils in coal strata which have been referred by unanimous consent to a vegetable origin, are those to which, from their reed-like appearance, the name *Calamites* has been applied; and they have been considered by M. Ad. Brongniart to belong to the natural family *Equisetaceæ*, and to possess very close and striking analogies with the *Equisetum*, or *Mare's Tail*, a common marsh plant. This opinion has, however, been disputed, and some Botanists have stated, that the Calamites must have belonged to a family of plants now totally extinct.

The remains of Calamites usually consist of jointed fragments, which were originally cylindrical but are now crushed and flattened. These fragments are supposed to be portions either of the trunk, or branches of a plant, which appears, from some of the larger specimens, to have attained the dimensions of a tree. Both stem and branches were deeply ribbed, or furrowed, along their whole length, and these ribs, or furrows again were crossed

at irregular intervals by horizontal rings, or articulations, at each of which the furrows turn in towards the centre of the stem; so that the stem was there very easily broken off. The extremities of the branches are usually found to be bent round at right angles to the stem; but sometimes the nearness to an extremity is indicated by the articulations becoming more numerous, the intervals between them smaller, and the stem diminishing suddenly to a point. One of the most remarkable characters in these plants is, the existence of a bark, which, according to Professor Lindley, is sufficient proof that the Calamite could not have belonged even to the class of Endogens, as the Equisetaceæ all of them do.



CALAMITES SUCKOWII. Brong.

Calamites, at any rate, may be described as branching plants with hollow stems, having a wood and bark distinctly separated. They attained considerable size, but must have been fragile and readily broken. Their whole substance was extremely soft, offering little or no resistance to pressure, and their internal cavity seems to have been separated by horizontal partitions at the articulations. The surface of the bark was marked by numerous parallel furrows often deeply chiselled on the stem, but running together and losing themselves in the partitions. Several species have been described (as many as nineteen from the coal measures in England); but the specific differences are, as might be expected, somewhat

obscure, since even the character of the leaves is uncertain, and the whole of our knowledge of the genus is derived from an examination of fragments of the stem.

The fossil remains of ferns are even more abundant than those of Calamites; but they consist almost exclusively of fronds in which the fructification is destroyed. These are found in all the shales and sandstones which alternate with the coal, and also in the nodules of ironstone associated with the coal in Wales and Staffordshire.

Ferns, as they are exhibited in tropical and southern climates, are not the subordinate and unimportant plants which they appear to be in European latitudes. Under more favourable circumstances as regards temperature and moisture, they are there expanded into lofty and picturesque trees, remarkable for their cylindrical stems, the tuft of leaves at their summit, and the regular disposition and shape of the marks, or *scars*, left upon the stem at those successive points, from which, at an earlier period of the growth of the plant, the fronds had taken their origin.* Such *tree-ferns* appear to have existed and

* "On descending to examine a tree-fern I found myself at the foot of one of their trunks, which was about five feet in circumference and ten in height. The lower part was a mass of protruding roots, and the upper part clothed with short remains of leaf-stalks looking rough and blackened; this was surmounted by dead leaves hanging down and nearly obscuring the trunk from distant view; above was the noble crest of fronds, or leaves, exceeding eleven feet in length, in various degrees of inclination between erect and horizontal, and of the tenderest green, rendered more delicate by the contrast with the dark verdure of the surrounding foliage. At my feet were several other ferns of large size, covering the ground, and which, through age and their favourable situation, had attained rootstocks a foot in height, crowned by circles of leaves three times that length. Other plants of tree-fern, at short distances, concealed from my view, by their spreading fronds, the foliage of the lofty evergreens that towered a hundred feet above them."—Backhouse's Narrative of a Visit to the Australian Colonies, page 35. See the vignette at the end of this chapter, copied, by permission, from one of the admirable sketches in Mr. Backhouse's work.

Another genus of tree-fern is found in Norfolk Island, the trunk of which rises to a height of fifty feet, exhibiting its rich crest of fronds among the surrounding

abounded in England during the deposit of the coal strata; and their remains are so common, that it is clear the plants must have flourished and succeeded one another for a long succession of ages, occupying an important place in the flora of our island.

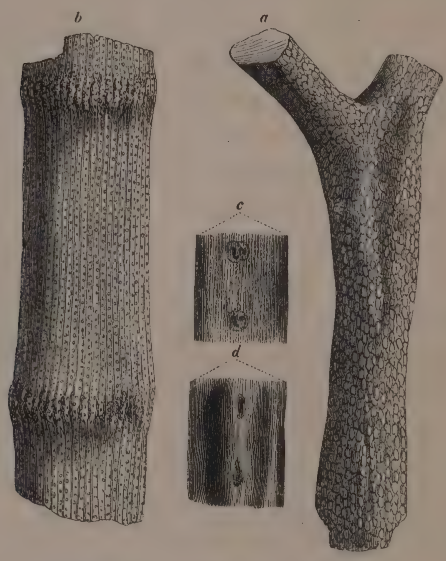
In consequence of the total absence of the fructification, the shape and method of venation of the fronds has been resorted to by M. Brongniart, in order to group together, in some way, the numerous remains of this large family of crytogamic plants. The whole have thus been arranged into a considerable number of genera, characteristic species of which are represented in the engraving at the commencement of this chapter, (see p. 245.) These genera comprise, however, the leaves only; the stems that have been found are included in one group under the name *Caulopteris*. It will be readily seen, that this arrangement is only for present convenience, for the fragments of stems unquestionably belong to some one or other of the genera determined by the leaves, although, as the stems and leaves have not yet been found attached, it is impossible to identify the one with the other. It should not be forgotten by those who have opportunities for collecting coal plants, that the remains of the stems of tree-

CAULOPTERIS. Lindl.

verdure, and forming a striking object in the landscape. The fronds are from seven to twelve feet long, and are produced in such abundance that this noble fern exceeds even the princely palm-tree in beauty.—Backhouse, page 251.

ferns are of extremely rare occurrence; and that, in every instance in which they are found, more especially if they have the slightest fragment of a frond attached, they should be carefully preserved, and at once communicated to some good Botanist accustomed to examine fossil plants.

A considerable number of the organic remains of vegetable origin found in the coal-fields of the north of England, consists of fragments of the stem and branching trunk of a tree which has received the name "*Lepidodendron*," from



a. LEPIDODENDRON STERNBERGII. Brong.
b. SIGILLARIA. (?)
c. *d*. The striæ and scars on the trunk and joints of (*b*) of the natural size.

the peculiar marks, or scars, observable along the whole length of its stem. Portions of such trees have been found as much as forty feet in length, and upwards of four feet in diameter. Narrow sharp-pointed leaves, resembling scales,

are sometimes associated with them, and appear to have belonged to them; and, in the same strata in which the trunks and leaves occur, cones of various dimensions (*Lepidostrobi*) are also more or less common. These cones consist of small scales which formerly covered and concealed seeds, and they are presumed to exhibit the fructification of the Lepidodendron.

In examining the various specimens of Lepidodendra, the Botanist usually finds four characters by which he may compare them with recent genera, viz., their surface, foliage, ramifications, and texture.*

With regard to surface, the leaves are arranged in the same manner as has been observed in certain coniferous plants, which they also very much resemble in the scars or marks produced by the falling of the leaves; but in both these respects they offer quite as much resemblance to the Lycopodiaceæ, or club-mosses, as they do to the Coniferæ. In the foliage, however, although it is strikingly like that of some of the club-mosses, the Lepidodendron accords still better on the whole with Coniferous plants, and amongst them with the Norfolk Island Pine.†

In the manner of branching the extinct genus is more nearly related to the Lycopodiaceæ, the branches not arising from opposite sides of the main stem and at the same height, as they do in the cone-bearing tribe, but bifurcating whenever a new bud is brought into action, so that all the divisions are forked.

* Lindley and Hutton's Fossil Flora, vol. i. p. 17.

† "The Norfolk Island Pine towers a hundred feet above the rest of the forest, some of the trees are nearly two hundred feet high, and we measured one twenty-three feet, and another twenty-seven feet, in circumference. It grows, both in clumps and singly, on the grassy parts of the island, to the very verge, where its roots are washed by the sea in high tides. In figure this tree resembles the Norway Spruce, but the tiers of its branches are more distant."—Backhouse's Australian Colonies, pages 251 and 265.

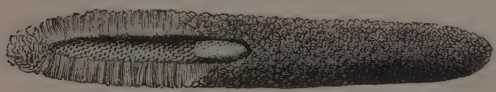
The texture and proportions of Lycopodiaceæ and Coniferæ are extremely dissimilar. The former contain among their existing species only soft cellular plants, with small creeping or erect stems of a few inches, or at most three or four feet in height, which have no bark and possess an imperfect woody axis. The latter are well known to form a group of large trees having a thick bark, and a hard woody centre, incapable of compression by ordinary force. The Lepidodendron* seems to have been characterised by the vascular tissue forming a continuous cylinder, not interrupted by medullary rays, and, therefore, not putting on a radiated appearance. In this respect it resembled the Lycopodiaceæ, and specimens are frequently found so compressed as to be nothing more than a thin plate, a condition clearly indicating the softness of the original stem. In respect of magnitude, however, the difference is exceedingly great, the extinct Lepidodendron having been a perfect forest tree, possessing, according to Professor Lindley's account, a true bark, although much thinner than the bark of recent pines.

On the whole, therefore, it appears to be the most reasonable opinion, and that which corresponds best with the results of investigation, to consider the genus Lepidodendron as occupying an intermediate station between the singular club-mosses, or Lycopodiaceæ, and the great tribe of cone-bearing trees; and that, although in some respects it approximates to the latter type, it possesses still closer analogies with the former, and must be placed amongst the vascular Cryptogamous plants not far removed from the Lycopodiaceæ and ferns, but forming a link between two

* Archives du Museum, vol. i. p. 405. Obs. sur la structure interieure du Sigillaria, &c., par M. Ad. Brongniart.

natural orders connecting the Gymnosperms with the Acrogens.*

Neither the leaves (*Lepidophylli*), nor the cones (*Lepidostrobi*), already alluded to, have yet been found attached to fragments of the stem of Lepidodendron; and they are, indeed, much more frequently associated with Calamites and ferns, so that they cannot be taken into account in deciding upon the former genus.



LEPIDOSTROBUS ORNATUS. Brong.

In appearance this cone (*Lepidostrobus*) resembles the young shoots of pine trees; it possesses a conical axis, round which a number of scales were compactly arranged from the base upwards; but the axis appears to have been soft and pliable, and instances occur in which the cone has been bent almost double without being at all fractured.

The plants which have hitherto been described belong either to the Acotyledonous class, as the Ferns, or to the Monocotyledons, and on the whole, they constitute the simplest forms of vegetation; but there have, also, been met with among coal plants unquestionable evidences of

* The *Gymnosperms* are included among Exogenous plants, with which they correspond in their general structure and in the growth of the stem, but they exhibit the reproductive system of flowering plants in its very lowest degree of developement. The best known order which the class includes, is the *Coniferæ*, or Pine tribe, and the lofty stems of these trees are composed of a peculiar and simple form of woody fibre, without perfect spiral vessels. The *Acrogens* are so called, because they include plants whose mode of growth is by addition to the point, or extremity, of previously formed parts, and are thus distinguished from Endogens and Exogens. The ferns are types of this class, and one passage from it to the previous one is through the singular tribe of *Lycopodiaceæ*, or the club-mosses. Another, and far more perfect, is obtained from the extinct fossil plants of the Carboniferous period.

Dicotyledonous structure, and a genus has been formed, under the name *Pinites*, to include a number of specimens of fossil wood, in which the structure, as seen under the microscope, exhibits an approximation to the true woody fibre of the Coniferous trees. Some of these specimens are of considerable size, one fragment of the trunk of a tree having been found seventy-two feet long, and another about half that length.

This genus is associated by M. Brongniart with two others ("*Sigillaria*," and "*Stigmaria*,") into a group resembling the Coniferæ and the Cycadeæ in the general arrangement of their woody texture, but uniting with that structure the most essential characters of the vascular system of Ferns and Lycopodiaceæ; an association which, till lately, would have appeared to announce an organization quite peculiar, but which is now known to exist, also, in a recent plant, the *Zamia integrifolia*.*

STIGMARIA FICOIDES.†
BRONG.

The genus Pinites has been already mentioned as referring only to fragments of fossil wood, in which the microscopic structure offers certain resemblances to that of coniferous wood. *Sigillaria*, on the other hand, comprehends a vast multitude of stems found in the same strata, often columnar, and of considerable size, varying from a few inches to three feet in diameter, and attaining a length of forty or fifty feet. These stems do not exhibit any internal woody structure, and have evidently been hollow, or of little substance, the flattened and

* Archives du Museum, vol. i. See M. Brongniart's Memoir before cited.

† The lower figure represents one of the scars of the natural size.

squeezed stem being often extremely thin, and composed entirely of sandstone, with an outer covering of coal, sometimes as much as an inch in thickness, which represents what was originally the bark of the tree.

The fragments which compose the genus Stigmaria consist also apparently of stems, whose diameter varies from two to six inches, but which are usually of considerable length and much compressed. Such cylindrical stems appear to have extended in all directions from a great central mass of vegetable matter, (in one specimen this mass is nearly three feet in diameter,) and the whole surface was covered with wrinkles caused by depressed semicircular spots, in the centre of each of which is a rounded scar. The spots are arranged in a spiral manner, and a little fine coaly matter usually adheres to the middle of the scar.

The markings by which the genus Sigillaria is known, consist of flutings of moderate breadth, with a single row of small scars between them, and these are said to be generally, but not always, indistinct on the lower part of the larger stems.*

The condition of the scars in this genus is such as to prove that the leaves were articulated on the stem, being connected with the woody or central axis by vessels that passed through a thick cortical mass of the nature of true bark, and which was separable freely without tearing from the woody axis.†

* I have ventured to figure as a Sigillaria a remarkable and undescribed fossil plant in the Geological Museum of the University of Cambridge. The singular joints at intervals along the trunk would seem to justify in this case the establishment of a new genus of extinct vegetables; but in a subject so surrounded with difficulties I hardly dare venture to offer any suggestion of my own. See figure, page 256.

† Lindley and Hutton, Fossil Flora, vol. 1. p. 155.

Until the publication of the memoir already quoted from the *Archives du Museum*, there had been no instance recorded in which the stem of Sigillaria was so well preserved as to exhibit any marks of its internal texture; but a specimen completely agatised having been found in the coal-field of St. Etienne, and forwarded to M. Ad. Brongniart, it became the object of minute examination. A vascular and fibrous structure was observed to characterise it throughout, which, with the traces that remained of the cellular tissue, (very faint, except towards the exterior, but there perfectly preserved,) have given an insight into the structure, and proved that the Sigillaria must be classed among Exogenous plants.

The great abundance of the large stems referred to this genus is a fact which seems to show, that it was one of those to whose presence much of the solid matter of the coal is due. Many instances are known in which trunks or stumps of large trees of this kind are found close together in an erect or highly inclined position; and this not only in England, but also in the continental coal-fields, and more especially in that of St. Etienne, where a remarkable group has been described by M. Alex. Brongniart.* It must not be supposed, however, that the trees grew upon the spot where they are thus singularly arranged; it is more probable that they have been caught and stopped in their passage down a rapid stream, and, like the *snags* on some of the great American rivers, have been detained till the lower portion was firmly imbedded in the rapidly forming sandstone.

Fragments of the supposed stems of Stigmaria are even more abundant, especially in some localities, than those of Sigillaria, scarcely a coal-mine being opened, or a

* See *ante*, page 225.

heap of shale thrown out, without numerous specimens being obtained. They appear, however, to occupy a particular position with reference to the coal, occurring most frequently * in a bed called the "underclay," which is even more persistent than the coal itself, and is constantly found below every one of the regular seams of coal in South Wales.† This underclay is an argillaceous bed, mixed with a certain proportion of sand, and the long slender processes given off from the stems of Stigmaria form an entangled mass traversing the bed in every direction, vertically, horizontally, and obliquely. It has been the opinion of many excellent Geologists, that there is some essential and necessary connection between the existence of this plant and the production of true coal, and that the stores of fossil fuel, at any rate in England and America, are mainly due to its presence.

The cylindrical stems already described as the most common remains of Stigmaria are distinctly marked outside with circular tubercles, and their axis consisted of a woody core communicating with those tubercles by woody elongations. But between the core and the bark there appears to have been a considerable interval filled with succulent matter, as the core is frequently excentrical, and the compression of the stem is almost universal.

It has not escaped the observation of those who have de-

* See a paper by Mr. Logan on this subject, Trans. Geol. Soc. 2d ser. vol. vi. p. 491.

† "So thoroughly is the Welsh miner persuaded that the two things (the coal-seam and the underclay) are essentially conjoined, that he would as soon expect to live in a house without a foundation as to work in a coal-seam which did not rest upon underclay." And again, "This fossil (the Stigmaria ficoides), taking for granted that the slender fibrous impressions belong always to it (they have often been traced to portions of stems of whose identity there can be no doubt) so completely fills every bed of underclay that it is not possible to cut out a cubic foot which does not contain portions of the plant."—Mr. Logan's paper already cited.

scribed these fossil plants, that the mass of vegetation, from which the apparent stems called Stigmaria take their origin, may possibly be the lower part of some large extinct plant, with numerous roots attached to it. This view of the case is probably correct; and I shall now conclude this account of the coal plants with the observations offered by M. Ad. Brongniart at the close of his Memoir on the Sigillaria and Stigmaria, as offering the most rational account of these extinct forms of vegetable existence, so widely different from species to which we are accustomed.

M. Brongniart observes, in the first place, that it is impossible to doubt the Dicotyledonous character of Sigillaria, and that all probabilities are in favour of the true position of that genus being among the Gymnosperms, although the difference between the structure of the fossil wood and that of recent Coniferæ and Cycadeæ, especially with regard to the former, is so considerable, that this position cannot yet be asserted as a positive fact.

In the second place, that Stigmaria is closely analogous to Sigillaria, and differs from it chiefly in a point in which the former more resembles Zamia; and that, notwithstanding this difference, the two genera, if distinct, belong to the same family of plants, referrible to the division of Gymnosperm Dicotyledons, but of which we are not at present acquainted, either with the leaves or the fruits.

Thirdly, that the fragments called Stigmaria are probably the roots of Sigillaria, the great uniformity of the specimens of the former agreeing well with the small differences of appearance observable in the roots of different species of plants; while the creeping habits of the supposed branches, and the rounded form of the scars also add to the probability, against which the regular arrangement of

the rootlets seems almost the only objection that can be raised; and even this peculiarity is not without parallel in the roots of some aquatic plants.

Lastly, this notion of the true nature of Stigmaria corresponds with the appearance of those singular domes of vegetable matter from which the supposed stems take their origin, and extend horizontally in all directions: it also explains the abundant interlacing, resembling that of small rootlets, noticed in the underclay; and even the presence of a woody pith in the centre of the ligneous trunk would be no sufficient objection to such a view, because the roots of many Zamias offer a similar peculiarity, the structure being more particularly observable in the roots of *Zamia pungens*, where the tissues offer on a small scale a repetition of those of Stigmaria.

I have now sketched as briefly as possible, and without attempting to enter on any description of species, some of the main features of that peculiar vegetation which characterised the carboniferous period; but it should on no account be forgotten, that our knowledge, valuable so far as it is positive, must not be supposed complete, nor may we for a moment assume, that we have even an average selection of the most common forms of vegetation which existed in this part of the earth at the time of the deposit. The experiment instituted by Professor Lindley on this subject, and already alluded to, is quite sufficient to show the utter worthlessness of any such conclusion; and all the arguments that may be founded on the absence of any one family, or the predominance of some other whose remains are abundant, at once fall to the ground. And, on the whole, it does not appear safe to assert more on the subject of the coal, and the nature of the vegetation on the adjacent land at the time of its deposition, than that "the

earth at that period was covered with a rich vegetation, of which only a small portion has been preserved; and that of this portion all the species and several of the races are totally unknown at the present day; and although it is probable, that the climate may have been something milder than it is now, there is no evidence in the vegetable kingdom to show, that it was materially different from that of the present day."*

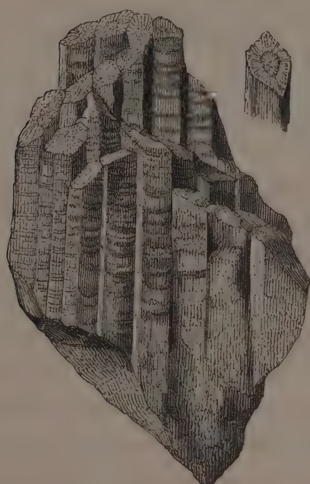
* Penny Cyclopædia, vol. vii. p. 296.

A TREE FERN.

CHAPTER XVII.

FOSSILS OF THE NEWER PALÆOZOIC PERIOD.

THE FOSSIL REMAINS OF ANIMALS.



CYATHOPHYLLUM BASALTIFORME.* PHILLIPS.

THE remains of vegetables described in the last chapter are chiefly, though not exclusively, confined to the coal-measures; but these form a very inconsiderable proportion of the whole mass of strata of the carboniferous period, almost all of which are exceedingly remarkable for the remains of organized bodies found in them. I pro-

* Lithostrotion striatum. Fleming.

ceed now to give a short account of these, so far as they are peculiar to the formation and possess any special interest.

The great mass of the mountain limestone has been formed by the agency of myriads of minute animals nearly allied to those which are still effecting constant and not imperceptible changes in the solid structure of the globe, by forming coral islands and reefs in the tropical and southern seas. The internal anatomy of these coral animalcules is so simple as to consist of little more than a stomach and secreting organs, the latter enabling them to separate from the sea-water a quantity of carbonate of lime with which they build their habitations. Simple as their structure is, however, they appear to have been, from the very earliest period of the world's history, among the busiest and most effectual of all living creatures in modifying the physical features of the globe. And in this respect the Madrepores, which are now at work, differ probably but little from the extinct Cyathophyllum, (see figure at the head of this chapter,) Lithodendron, and others, as a proof of whose existence we have only to point to the solid rocks of the carboniferous system, forming mountains which have for ages past been exposed to all the changes and circumstances of time and chance. A consideration of the general resemblance of the mountain limestone corals to those now living in the southern seas, and the nature and extent of the Palæozoic rocks made up of them, might alone be sufficient to satisfy those who question the magnitude of geological phenomena and the ages required to produce them.

The remains of those radiated animals, called by the Palæontologist "*Encrinites*," are so extremely abundant in the mountain limestone,—their fragments forming in

Derbyshire and elsewhere a considerable mass of solid rock, — that although many very remarkable species are found in other formations, it is necessary here to introduce the subject, and explain the nature of the animal whose skeleton is thus preserved.

The class Radiata of Cuvier comprises a number of animals which connect the simple Polyps, on the one hand, with the Articulata on the other, by means of a series of links, named respectively *Crinoideæ*, *Asteridæ*, *Echinidæ*, *Holothuridæ*, and *Fistularidæ*, of which the three former are abundantly represented in a fossil state; and the first, or least highly organized, is that to which at present our attention must be directed. The two last, which are the most highly organized, are known only in a recent state, the animal not possessing any calcareous covering or skeleton, and therefore not capable of being preserved and handed down to us, even if it did exist at the time of the formation of the older rocks. The Echinidæ, or sea urchins, first appear in rocks of the Oolitic period; but the Asteridæ, or star-fish, are represented in all formations, from the Lower Silurian upwards, at least two species of *Ophiura* being known to occur in the Older Palæozoic rocks. The Crinoideæ also appear in the Silurian strata; and in some strata of the carboniferous period they occupy an important place, entire rocks being made up of their fragments.

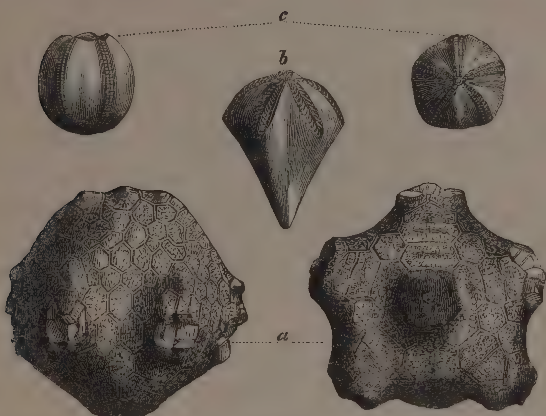
The Crinoideæ, as a family, are remarkable at once for the simplicity of their organization and the peculiarly complicated structure of their calcareous skeleton; and had it not been for two or three species still existing in a recent state, the Naturalist might have speculated for a long time on the possible origin of so singular a stony column as this animal possesses, and the probable habits of the creature itself. The animal, however, being known, is found to

resemble closely a true Polyp or coral animalcule, and its body consists of a delicate gelatinous tube, contracted at one extremity, by which it is attached, and furnished at the opposite end with a variable number of delicate contractile filaments placed round the opening which represents the mouth.

Let us now suppose an animal thus simply organized, but supported upon a prolonged stem, and instead of depositing earthy particles externally, and so forming coral, depositing them within its body, so as to fill the pedicle or tube by which it is attached, and encase the body or stomach, and the filaments about the mouth, by solid pieces of definite form, connected together and forming an internal flexible skeleton. A polyp so constituted would be an encrinite, and it will readily be seen that the skeleton may consist of thousands, and even tens of thousands, of regularly shaped pieces of calcareous earth, kept together by the tough coriaceous membrane which surrounds and encloses them during the life of the animal, but usually separating after death and when decomposition has taken place.

Little more than this is known of the structure of Encrinites, or the habits and peculiarities of the different genera. They appear to have been exceedingly gregarious, crowding together in groups, and we may picture them to ourselves, each one attached at its base to the solid rock, and the body at the extremity of the long but flexible stony column waving gracefully in obedience to the movements of the expanded arms, which, under ordinary circumstances, would be widely spread to catch and conduct to the stomach any prey that might come within their reach. At the approach of danger the arms would be drawn in—the stony plates brought into contact, and the

whole animal reduced to the smallest possible dimensions, offering nothing to the attack of an enemy but a solid framework of stone.



a. ACTINOCRINITES TRIAKONTA-DACTYLUS. MILLER
b. PENTREMITES INFLATUS. SOW.
c. P. ORBICULARIS. SOW.

There are several genera more especially characteristic of the mountain limestone, and amongst them is the *Pentremites*, of which two common species are figured. In another genus, the *Actinocrinite*, sometimes called " the nave Encrinite,"* the column is formed of many joints, on whose summit are pentagonal plates, forming a basin or pelvis, supporting five hexagonal plates and one which is pentagonal. To these, again, another series is attached, and then five columns or arms are given off from each of them, which subdivide first into two branches, called

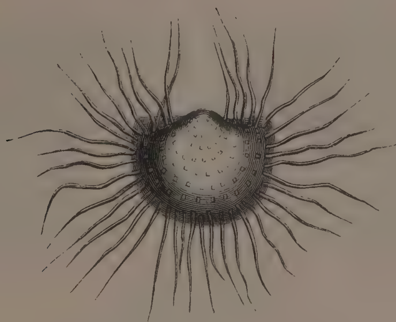
* Parkinson's Org. Rem. vol. 2, pl. 17, fig. 3. The name triakonta-dactylus (or thirty-fingered) is derived from the number of final branches—the pelvis, as mentioned in the text, supporting five plates, each of these two, and each of these again three, so that six fingers proceed from every one of the five arms, making, in the whole, thirty columns, which, with the stony fringe appended to them, formed a kind of net-work to entrap the prey on which the animal fed.

hands, and each of these again into others, called fingers. This encrinite attained a considerable size, but the plates in all cases must have adhered by muscular attachments and ligaments, since they have no regular articulating surfaces, but only a rough corrugated side, to which the muscles were doubtless fastened. In this species there appears to be a somewhat remarkable peculiarity, the number of arms not being the same as that of the plates supported by the pelvis, as it is in other encrinites. This difficulty, however, is obviated by the supernumerary plate being pentagonal, the others being hexagonal. The arms appear to have been of moderate length, and the fingers are formed of two series of joints.

Proceeding now to the invertebrata of higher organization, we find in the beds of the Newer Palæozoic period a very large number of species of mollusca, all of them extinct, but many differing little in appearance from more recent forms. While, however, this is the case with many species, it is not so with all; and amongst others, the remains of Brachiopoda, which are characteristic both of the mountain and magnesian limestone, possess considerable interest: they are chiefly confined to two genera, "*Productus*" and "*Spirifer*," and these two occupy a most important position among the shells of the carboniferous series.

The genus Productus has received its name from a peculiarity observed in several species where the dorsal valve, after having attained a certain magnitude, bends suddenly at right angles to its former direction, and is then continued irregularly, sometimes being produced to a considerable length. The whole shell is usually covered with striæ and spines, which in some species are numerous and very long, and which appear to have been moveable,

doubtless serving a purpose in the animal economy. The manner in which the Productus was attached, and even the fact of its having been attached, is not certain; but it



PRODUCTUS SPINULOSUS. Sow.

has been very ingeniously suggested by M. L. de Koninck,* that a set of muscular fibres may have passed between the open edges of the two valves, approximating the Brachiopoda in this way to the Cirrhipodous molluscs. Such a link, if it really exists, is the more interesting, from the analogies already known between these two remarkable groups.†

The Spirifer is a Brachiopod, closely resembling the Terebratula in many important characters, but differing from it in the singular spire of calcareous matter passing across the interior of the shell, and from which the name of the genus is derived. Upwards of fifty species of this genus have been recorded from the Newer Palæozoic rocks of England; but they are not confined to that period, at

* Fossiles des Terrains de Transition de la Belgique, p. 153.

† There is one species of Productus (*P. calvus*) which is interesting from its abundance in the magnesian limestone, where it is almost invariably found if fossils at all are present; but it is also found throughout the mountain limestone, and cannot therefore be considered characteristic.

least thirty others occurring in the Devonian formations, and some few even in the Lias, which overlies the whole Palæozoic group and the New red sandstone. Next to the

SPIRIFER STRIATUS. Sow.

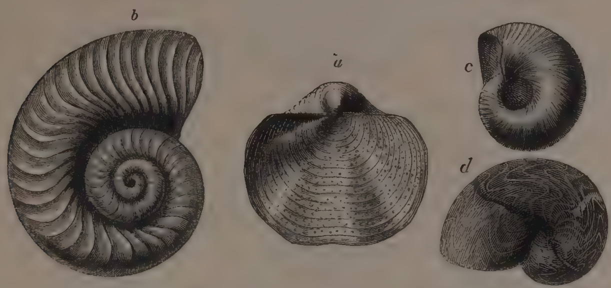
a. View of the external Shell.
b. Interior, showing the Spire.
c. Portion of the Spire detached.

Terebratula they are the most abundant of all Brachiopoda, and are for this reason important to the Geologist in identifying formations, although the determination of species is still somewhat obscure and unsatisfactory.

The other bivalve shells of the carboniferous system are numerous, but offer no points of general interest. Of the univalves, several species resemble those still existing; and these form a large group, presenting certain analogies, as well as differences, which perhaps hereafter, when they have been studied more with a view to general results, may enable the naturalist to determine the circumstances under which they were deposited. The genera most characteristic are, perhaps, the CIRRUS, EUOMPHALUS, and BELLEROPHON, concerning each of which I shall say a few words.

The *Cirrus* appears to have been the shell of a molluscous animal, which, like the snail and many other recent genera, inhabited a spiral shell, constantly increasing by additions at the mouth, and sometimes growing to a very large size. *Euomphalus* is the shell of another gastero-

podous mollusc, and, together with the "Cirrus," is extremely abundant in some parts of the mountain limestone. The shell is often exceedingly thick, and is divided irregu-



a. PRODUCTUS FIMBRIATUS. Sow.
b. CIRRUS TABULATUS. Phil.
c. BELLEROPHON TANGENTIALIS. Phil.
d. GONIATITES STRIATUS. Phil.

larly into a number of compartments or chambers, not, like those of the Cephalopoda, provided with a tube running through them, but solid, and entirely shutting off at intervals that part of the shell in which the animal dwelt, from the smaller and uninhabited portion. These empty spaces served, no doubt, as floats, rendering the whole mass of the shell and animal sufficiently light to move easily in the water.

The *Bellerophon* is a very singular shell, and the nature of the animal inhabitant can only be guessed at. The shell seems to resemble, in some respects, that of the monothalamous, or single-chambered Cephalopoda, such as the Argonauta; but the points of difference are numerous and striking, and naturalists have lately been inclined rather to include the genus in a different order called "Heteropoda."* Considerably more than one half of the whole number of known species are from the Newer Palæozoic rocks, and the rest from the Devonian and Silurian forma-

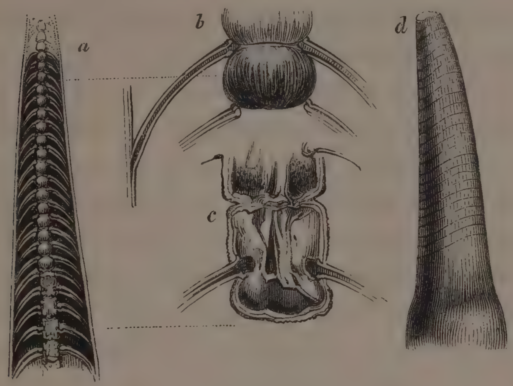
* It is not unlikely that the true position of this genus is among the Pteropoda.

tions, and the form of the shell differs so much in different species that it is not very difficult for the geological student to obtain a sufficient knowledge of those which are most characteristic. They are abundant in the mountain limestone and are associated with Goniatites in the shales of the culmiferous bands in Devonshire, and in some other shales of the coal-measures.

The *Goniatite* is a genus to which allusion has already been made, in speaking of the Devonian fossils. It is, however, even more abundant in the limestone and shales of the carboniferous system than in Devonian beds, and of fifty-seven described species from England nearly fifty are from the former. The nature of the transition from the Clymenia to this genus will be seen, by comparing the markings in the specimen figured in the last page with the figure, page 179. The siphuncle in the Goniatite is strictly confined to the dorsal margin, and is usually very small, while the septa are deeply indented, and are drawn forward in prominent angles towards the aperture.

Lastly, the form which the siphuncle sometimes assumes in the Orthoceratite and genera nearly allied, is also developed in its extreme in the Carboniferous limestone; and an instance of this is well seen in the annexed engraving, which represents a specimen of great beauty in the Woodwardian Museum of Geology in Cambridge. This specimen was obtained from Ireland, but the same species also occurs in the red mountain limestone of Dumfries-shire, in Scotland. The singular way in which the siphuncle is expanded within each chamber, and the complicated appearance it presents, has induced some Palæontologists to separate this genus from Orthoceratite; but it is doubtful whether there existed any external difference, or whether the proportionate size and internal structure of the siphuncle

can be considered of sufficient importance to justify the establishment of a new genus.



ORTHOCERATITES.

a Section of Orthoceratites simmsii.* STOKES.
b. Siphuncle of Ditto, showing the corrugated exterior surface.
c. The same exhibiting the interior of the Siphuncle.
d Orthoceratites laterale. PHILLIPS.

About thirty species of Orthoceratites are described from the English carboniferous system, and no species has ever yet been discovered in any formation of newer date. The Cephalopoda of the Secondary rocks differ entirely from those of the Palæozoic group, being, like the fish, developed in a totally distinct form in the newer strata, and changing much more abruptly than appears to be the case with other less highly organized species.

The remains of the palatal bones and teeth of fish are occasionally found in the carboniferous limestone, and have been described by M. Agassiz, and referred by him to nearly 120 different species; they are chiefly met with in Ireland (Armagh), in the coal-measures at Burdie House, near Edinburgh, or at Newhaven, also in North Britain.

* Actinoceras simmsii.—Bronn. Geol. Tr. 2d ser. vol. v.

Some of them, as the *Megalichthys* and the *Holoptychius*, (already described,) are remarkable for their large size and striking peculiarities of structure; but the greater number are only known by imperfect fragments. For detailed descriptions of these I must refer to M. Agassiz's great work on fossil Ichthyology.

The *Megalichthys* is one of those genera which may rank amongst the singular links connecting two great natural divisions, which are apparently so strongly marked, and separated from one another so widely, as to offer scarcely any points of resemblance. It combines, with many of the characters of a true fish, many close and striking analogies with reptiles; and the teeth, more especially, so closely resemble those of some crocodilean animals, that when first discovered they were immediately referred to that class; and not only the teeth, but the scales also seemed to Dr. Hibbert (by whom they were first noticed) to indicate the same affinity.

There exists, however, a family of Ganoid fish, containing many extinct genera, represented in existing seas by two genera,* which together include seven species, in which the peculiar Sauroid character of the teeth indicates this approach to the reptiles, which seems carried to its height in the genus now under consideration.

The dimensions of the teeth of the Megalichthys far exceed those of any other fishes' teeth that have yet been examined, one of them having been found to measure nearly four inches in length, with a breadth at the base of nearly two inches. They are, however, of two kinds, the large teeth being accompanied by several very small ones, alternating with them, and distributed over the whole of the inside of the mouth. The teeth are coni-

* Lepidosteus and Polypterus.

cal, and possess a conical hollow at the base, in which the next tooth is prepared, so that there may be a constant succession, as in reptiles.

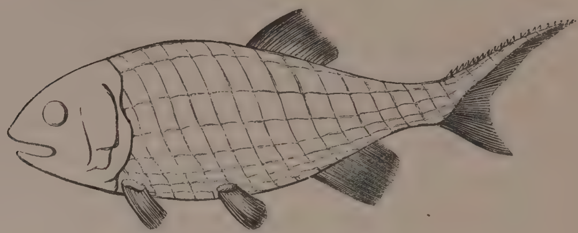
The scales of the Megalichthys are of various forms, and exhibit a coating of enamel of a nut-brown colour, and of the most brilliant lustre. They are generally angular, and the surface is punctured like that of the dermal scutes of the recent crocodile. Besides, however, the angular scales, others have been found rounded, and of large size, having externally a lamellar structure, and not exhibiting the shining enamel so characteristic of the scales of Ganoid fish. The rounded scales have been found as much as five inches in diameter.

Besides, however, the remarkable analogy with reptiles exhibited in the teeth of Sauroid fishes, M. Agassiz has also remarked, "that the osteology recalls in many respects the skeletons of Saurians, both by the closer sutures of the bones of the skull, and by the manner in which the spinous processes are articulated with the body of the vertebræ, and the ribs at the extremity of the spinous processes." *

But although the species of fish determined from the mountain limestone and the beds associated with it, are more numerous than those found in the magnesian limestone either in England or Germany, the interest attaching to these latter is, perhaps, even greater, because the remains are more perfect and more decidedly characteristic of the formation. They are strictly confined to the group of Heterocercal fish, and are, almost without exception, referred to the Ganoid order of M. Agassiz. The genera which are much more common than any of the rest in the Magnesian limestone of England, and the

* Edin. Phil. Journal, Jan. 1835.

Kupfer-schiefer of Germany, are four in number, two of them, *Palæoniscus* and *Platysomus*, belonging to the family of Lepidoides established by M. Agassiz, and the other two, *Pygopterus* and *Acrolepis*, to the family of Sauroid fishes.

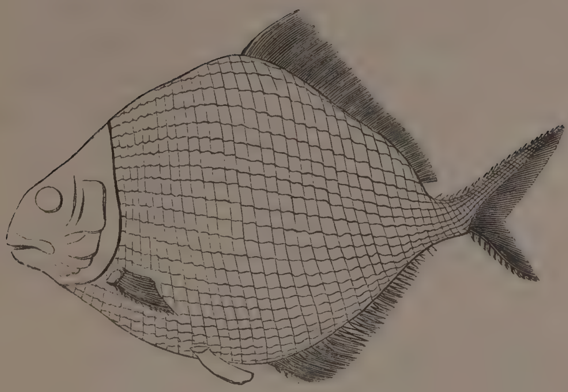


PALÆONISCUS. Ag.

The head of Palæoniscus is of a somewhat singular form, especially with regard to the anterior portion of the face, which forms a rounded projection above and before the upper jaw, occasioned by the swelling out and prolongation of some of the bones of the skull. The orbit of the eye is surrounded by a series of small narrow bones, and the mouth is usually large, but the teeth so exceedingly small that it is rarely possible to distinguish them. The jaws, however, are powerful, and more especially the lower one, which is larger than the upper.

The genus *Platysomus* differs considerably from Palæoniscus, as the body is of a trapezoidal form, is much raised, and nearly as high as it is long, while from the position of the scales on the edge of the back and on the belly it appears to have been flattened.

The head is large in proportion to the size of the body, the extremity of the snout forms a slightly rounded projection, the mouth is small and narrow, the jaws are armed with small but very pointed teeth, the lower jaw is



PLATYSOMUS. Ag.

shorter than the upper, and broader in proportion, and the operculum (or bony scale covering the gills) is narrow and much elevated. The whole body is covered with large scales.

One of the most remarkable peculiarities in the structure of this fish is, that although the body is flat, short, and elevated, like that of the recent flat fish, the tail instead of being, as in the latter, much forked and equally lobed — arrangements which appear in the present state of things to be indispensable—retains in the Platysomus the heterocercal character, the upper portion having the vertebral column continued into it, and being much larger and more powerful than the lower portion, which rather resembles a small accessory fin.

The other genera of Magnesian limestone fish, the Pygopterus and Acrolepis, belong, as I have observed, to the Sauroid family, and of the fish of this family some notice has already been given in speaking of the Megalichthys. I regret that I am not able to give any detailed account of either of these two interesting genera

so characteristic of the Magnesian limestone, but until an account of them shall appear in the great work by M. Agassiz on Fossil Fishes, now in course of publication, it would be presumptuous to hazard any description. Specimens of both genera are common, as well in the German Kupfer-schiefer as in the bituminous schist and magnesian limestone of Durham; they are of small size, and do not seem in any case to have exceeded two feet in length.*

Of the Saurian remains of the Newer Palæozoic period I shall not offer any minute description, as the interest attaching to them rather arises from the fact of their being the earliest species with whose existence we are acquainted, than from any peculiarities which admit of a popular description. They belong to a family of Lacertians, or Lizard-like reptiles, in which the teeth are planted in sockets, either loosely or confluent with the bony walls of the alveolar groove,—a point in which they differ essentially from existing Lizards.

* The completion of the "Poissons Fossiles" of M. Agassiz has been announced since these sheets were in type, but I have been unable to refer to the part recently published, as it has not yet, I believe, reached England. I shall take an opportunity of referring to the subject of the magnesian limestone fish in a future chapter.

CHAPTER XVIII.

GENERAL CONDITION OF THE GLOBE DURING THE PALÆOZOIC PERIOD.

I HAVE already in a former chapter, (at the close of my account of the formations of the older Palæozoic period,) summed up, to a certain extent, the Geology of the most anciently formed fossiliferous rocks, and directed the attention of the reader to the peculiar characteristics by which they are distinguished from the sandstones, limestones, and clays, of more modern periods. But it must not be imagined that this change was sudden:—it seems to have been, on the contrary, exceedingly gradual, and almost imperceptible, and was in the course of completion while the various rocks of the middle part of the Palæozoic system were being deposited. During this period there may be traced in different parts of Europe, in the adjacent islands, and in America, the effects of many distinct but contemporaneous operations; in one place a deposit of fine argillaceous mud loaded with the remains of marine shells, corals, &c.; in another a coarse sandstone and conglomerate, sometimes totally without organic remains, sometimes containing such fossils as are least easily destroyed, as the scales and teeth of fish; and over a third and very extensive district, these two kinds of deposit alternate with one another, or succeed one another, and the sandstone is fossiliferous, containing innumerable

casts of shells, while the clays associated with it, and altered into shales or slates, are non-fossiliferous. Of each of these I have given some account, and they form the three kinds of rocks, viz., the Devonian shales, the Old red sandstone, and the grauwacké sandstone, which predominate almost to the exclusion of other rocks in the Middle Palæozoic system.

Now there can be little danger in asserting, that the conglomerates of the Old red sandstone must have been produced, not only by violent but by long continued disturbance of the older rocks; for these conglomerates, as they occur in some parts of Scotland, are entirely composed of hard fragments of quartz and porphyry, which are broken, rounded, and polished, presenting every mark of violent and prolonged attrition at the bottom of the ocean; while the pebbles themselves are derived from almost every variety of ancient rock, so thoroughly mixed, that they must apparently have been rolled and tossed for ages in the troubled seas.*

But although the evidence of disturbance is thus so strong in the Old red sandstone, there is proof in the same formation of occasional intervals of repose, during which were deposited fine micaceous and bituminous schists, containing abundantly the fossil remains of fish in a nearly perfect state, and, in this respect, differing from the coarser conglomerates and sandstones both in the northern parts of our island and in Herefordshire. These intervals of repose, however, seem to have occurred only in certain parts of the formation, and the rocks then de-

* With reference to this condition of the Old red sandstone conglomerate, Mr. Miller observes, "I do not remember to have seen in it a single pebble which I could not have raised from the ground." Miller on the Old red sandstone of Scotland, p. 229, note.

posited do not offer any parallel, either in their mineral condition or fossil contents, with those formed by quiet subsidence in other parts of the ancient seas at the same period. It is only in Russia that there appears to be any passage from the one series into the other, and the circumstances under which this takes place are not yet sufficiently well known to justify any speculations on the subject.

As bearing upon the history of the rocks of the Middle Palæozoic period, it is worth while to notice the hills and mountain chains whose elevation seems to have occurred contemporaneously. In Scotland, the Grampians and the Lammermuir hills exhibit on their flanks no rocks more modern than those of the Middle Palæozoic period, but at the same time they often displace the rocks of the same age, and it is difficult to imagine that the granites and porphyries of those mountain chains were not in some way connected with the formation of the Old red sandstone; while certain peculiarities in the physical features of North Wales and Cumberland, seem to point to the same conclusion in those countries. Whether a long series of submarine disturbances and elevations, terminating in the formation of mountain chains, may, or may not, have been a sufficient dynamical cause of those great waves which have transported the conglomerates of the Old red sandstone, and ground the fragments of rock into small pebbles, rounding them by perpetual attrition against one another, is a question belonging to that department of Geology into which I have determined not to enter; and I, therefore, only allude to the possibility of such a cause, and do not at all discuss its probability or sufficiency. But in Herefordshire and Wales, where the conglomerates of the Old red sandstone are also common, there are not wanting hills

which appear to have been contemporaneous (the Malverns being the most conspicuous); while, on the other hand, the granite which bursts through the finer shales and sandstones of Devonshire and Cornwall, is of more recent origin than the culmiferous beds of the overlying system; and there does not appear to have been any considerable disturbance, or change of position, in those rocks until long after their deposition.*

The rocks of the Middle Palæozoic period are succeeded by the miscellaneous group of sandstones, limestones, and shales, which form the carboniferous system, and these again by the sandstones and magnesian limestones of the Permian system. In this long and greatly varied series, characterised throughout by peculiar organic remains, the far greater preponderance of limestones, mostly of organic origin, is a fact which ought not to be passed by without special notice. The limestones are, also, here less mixed with argillaceous matter, they are thicker and far more persistent than is the case with those of the Devonian or Silurian systems, and they are, in almost all cases, either semi-crystalline, or greatly disturbed by accidents subsequent to their deposition. This is not all: both the sandstones and the shales associated with them are here fossiliferous, and the fossils are of the vegetable and not the animal kingdom; so that the extreme abundance of carbon exhibited as well in the limestones, (carbonates of lime,) as in the beds of coal is a new and highly charac-

* The same is the case in those parts of the Continent in which the Devonian strata consist, as they usually do, of fine sandstones or shales. In the Hartz, for instance, there is a central mineral axis round which the Devonian rocks are wrapped, but the elevation is of comparatively recent date, and some rocks of the Secondary period are affected by it as well as the Devonian grauwacké. According to the observations of Mr. Murchison, the elevation of the Ural chain has, in part at least, produced the same effect as that of the Grampians in Scotland, and is connected with the Old red sandstone conglomerates of North-eastern Europe.

teristic feature. Here again, I merely wish to place the facts of the case before the reader, and do not offer any conjectures as to the causes by which the phenomena may have been produced. The quantity of carbon added to the solid materials of the globe during the formation of the rocks of the Newer Palæozoic period is, however, so remarkable, that it must be looked upon as the indication of a most important change in the condition of the earth; and it also seems to have rendered the earth fitter than before for the habitation of animals, and more especially of reptiles, which are first found in the newest beds of the Palæozoic group. We shall see, hereafter, how different in general appearance and lithological character, as well as in the nature of their organic remains, are those newer rocks which we call Secondary; and the suddenness of the change, so far as regards the introduction of new species, is an indication not to be misunderstood of the magnitude of the barrier that exists between the two groups of formations.

ICHTHYOLITE BED IN THE MOUNTAIN LIMESTONE OF GAMRIE.

SECONDARY FORMATIONS.

CHAPTER XIX.

THE UPPER NEW RED SANDSTONE AND THE TRIASSIC SYSTEM.

The great system of formations which has received the name of The Secondary System, and which is intermediate between the Palæozoic rocks and the Tertiaries, is readily subdivided into five groups, of which four are continuous throughout a great part of England and Europe, the fifth being local, and only extensively exhibited in a small district in the South-eastern part of our own island. The order in which these rocks occur, and the names by which they are most usually distinguished, will be understood by referring to the following tabular arrangement.

Secondary Period.	Newer.	5. Cretaceous group.
	Middle.	4. Wealden formation.
		3. Oolitic group.
	Older.	2. Liassic group.
		1. Upper new red sandstone, or Triassic group.

We have to consider in this chapter the most ancient of these groups, usually spoken of by English Geologists

as the New Red Sandstone, but which has recently received on the Continent the appellation of *Triassic*, from its being there subdivided into three very decided and well-marked formations.

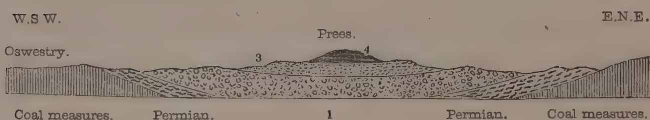
I have already mentioned, that, till very lately, the New red sandstone formation has been considered to include the magnesian limestone and extend to the coal-measures; but these lower beds which are quite distinct in Palæontological character, must for the future be ranked as true Palæozoic, and the Upper new red sandstone be referred to the Secondary period.

Wherever the magnesian limestone occurs in England, its edges are seen to be covered up by an extensive series of yellow or red arenaceous beds, alternating with red, green, or blue marls, which are rarely fossiliferous, and which often contain common rock-salt in great abundance, associated with crystals of gypsum. This whole overlying series is " the Upper New Red Sandstone."

In the east of France, however, and in Germany, where the Zechstein represents our magnesian limestone, we find the overlying beds differing considerably from the contemporaneous rocks in England, and admitting of a tripartite division, whence the name Triassic has been applied to them. The middle bed of limestone, the Muschelkalk of the Triassic system, being absent in England, it is extremely difficult, if not impossible, to draw an exact line of demarcation between the upper and lower sandstones, the absence of fossils adding to the difficulty, and the two series resembling each other closely in mineral composition and lithological character. Such an attempt has been made, notwithstanding this difficulty; and the sandstones and conglomerates of the middle of England have lately been declared to represent the lower Continental

sandstones, (*bunter sandstein*, or *gres bigarré*,) while the saliferous marls of Cheshire have been compared with the variegated marls, (*Keuper*, or *marnes irisées*,) of Germany and France.

NEW RED SANDSTONE.



SECTION ACROSS A NEW RED SANDSTONE BASIN.*
Oswestry to the North of Staffordshire.

Every one looking on a Geological map of England must be struck by the appearance of a great patch of colour, (usually some shade of red,) extending over a very considerable proportion of the whole surface, and which on examination is found to represent the bed we are now considering. The Geological student who is familiar with the districts so coloured, will be aware, also, of the general want of conformability of this red sandy rock with the other formations of more ancient date on which it reposes. It appears to have been deposited over most of the rocks in the central part of England long after they had been formed, and even after subterraneous disturbances had tilted and displaced them ; and it is easily recognized filling up the valleys and covering the plains, but rarely reaching to any great height, and for the most part very little disturbed from its original horizontality. Owing to the nature of the alternating marls and gypsum of this series of strata the vegetable soil arising from its disintegra-

* 4. Lower oolites.
3. Saliferous marls and sandstone.
1. Sandstone and quartzose conglomerates.

tion is extremely fertile; and in the greater part of the county of Devonshire, in the Valley of the Severn, and yet more strikingly in the agricultural districts of Warwickshire, Worcestershire, Staffordshire, and Cheshire, many peculiarities may be observed characterising this formation.

The beds which immediately overlie the magnesian limestone, or, in other words, those which are lowest in position of the Upper new red sandstone, are chiefly found in the middle of England, and consist of thick masses of whitish soft sandstone. In some places (as in Staffordshire) these are surmounted by conglomerates, filled with rounded pebbles of quartz rock, and other fragments, chiefly of Silurian rocks and Old red sandstone. The total thickness of this part of the formation is considerable, but has not been accurately calculated. It is not rich in fossils, and is only to be distinguished from the overlying saliferous marls by small differences of mineral character.

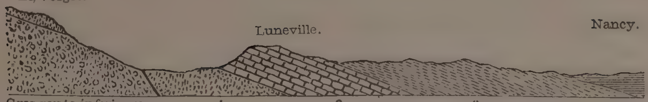
It is in Cheshire, the southern part of Lancashire, and the northern part of Shropshire, which together form an extensive and rich plain, watered by the Dee, the Mersey, and the Weaver, that the uppermost beds of the New red sandstone are chiefly developed; and by a minute examination of these beds, and those of Warwickshire, the saliferous marls have been identified with the uppermost strata of the foreign Triassic system. Throughout this range the beds are nearly horizontal, the dip rarely exceeding ten or twelve degrees, and being constantly towards the east, or a few degrees north or south of that point. The whole district abounds with salt springs, which are more especially plentiful in Cheshire; and in that county, also, there occur extensive masses of rock-salt in a solid

state, their total thickness amounting to not less than sixty feet. These alternate with beds of gypsum, with numerous bands of indurated clay of a blue, red, or brown colour, and with sandstones, frequently marly, and of a red colour.

The red marl district with brine springs is continued southwards into Worcestershire, and northwards into the valley of the Eden, and the same part of the formation extends also eastwards, occupying for the most part the plains through which the Humber and its tributaries make their way to the German Ocean. In Somersetshire and Devonshire similar sandstones recur, and lie unconformably, overlapping the inclined edges of the older rocks, or abutting against them, but composed of the same materials, remarkable throughout for the ochraceous colour pervading them. Between Sidmouth and Seaton in Devonshire, the red marls contain gypsum in abundance, and near Teignmouth the cliffs, which are of considerable height, consist of alternations of argillaceous beds of sandstone and of conglomerate.

The whole of the Upper new red sandstone, as exhibited in England, bears evident marks of its marine origin, even if the occurrence of so large a quantity of salt associated with it did not place the matter beyond a doubt. The almost total absence of fossils is, however, a very remarkable phenomenon, and one which is not satisfactorily accounted for, either by the prevailing sandy character of the deposit, or by the quantity of oxide of iron distributed through it. Some organic remains have indeed been found, and these, together with the impressions of the footsteps of various animals, often admirably preserved in the sandstone, will be described in the ensuing chapter.

THE TRIASSIC SYSTEM.



SECTION FROM THE VOSGES TO NANCY.*

I have already mentioned, that the beds immediately overlying the magnesian limestone, or Zechstein, on the continent of Europe, form themselves naturally into a tripartite group, to which the name of "the Triassic System" has been applied. The nature of this subdivision will be understood by referring to the annexed diagram, and comparing the references with the following table. In the section the newer beds rest unconformably upon the lower sandstones, as they often do in England; but in other districts on the continent the sequence is perfect, and the same order of succession obtains, without the interpolation of any other bed.

1. Bunter Sandstein, (*gres bigarré*,) a quartzose sandy deposit, which usually forms the base of the system, both in France and Germany.

2. Muschelkalk, a well marked and highly fossiliferous limestone, rarely absent in the continental series, but never found in England.

3. Keuper, (*marnes irisées*,) a singular group of sandy marls of variegated colours, frequently containing salt and gypsum, and remarkable for numerous vegetable remains found fossil in them. The Keuper is supposed to correspond with the upper variegated and saliferous marls of England.

* 3. Keuper. Marnes irisées.
2. Muschelkalk.
1. Gres bigarré. Bunter sandstein.

(1.) The GRES BIGARRÉ, or BUNTER SANDSTEIN, is a fine-grained solid sandstone, sometimes white, but more frequently of a red, blue, or greenish tint. The structure of the lower part is tolerably close-grained, and sufficiently compact to form a good building stone; but the uppermost strata are fissile and incoherent, and pass into an earthy clay containing gypsum. The intermediate portion is compact, like the lower, but its structure is that of a conglomerate, and it is used for making millstones. In many districts the Bunter Sandstein contains numerous remains of fossil plants, and also of marine shells; but the latter are rare and confined to particular localities.*

The sandstones and marls of this part of the series are spread over an extensive tract of land in western Europe, more particularly in France, and in south-western and central Germany. They are found in France, on the banks of the Vosges, where they overlie the Lower new red sandstone, (there called "*gres de Vosges*,") and again in several parts of central France, and in the Sub-Pyrenees.

On the right bank of the Rhine, in Swabia, there are some districts in which the bunter sandstein rests immediately on the rothe-todte-liegende, the gres de Vosges being absent, and no other representative of the magnesian limestone taking its place.

(2.) The MUSCHELKALK is a compact limestone of a grey or greenish-grey colour, and commonly contains in great abundance the remains of shells and fragments of radiated animals and fishes.† It rests conformably on the gres bi-

* It appears, however, from the researches of Mr. Murchison and M. de Verneuil, that a portion only of what is called *Bunter Sandstein*, in Germany, properly belongs to the Triassic group. Another portion, marked by the presence of some fossil plants, has been shown to belong to the Palæozoic period.

† It occasionally, however, becomes magnesian, and loses all marks of organic remains, and in some districts again is argillaceous and earthy, passing insensibly into the overlying marls of the Keuper.

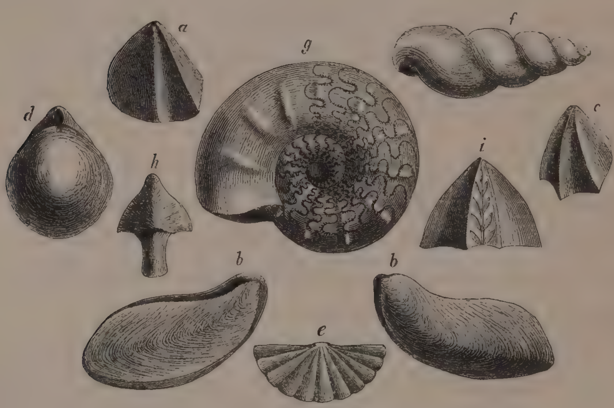
garré, and either forms an escarpment, or is well exhibited in a range of high table land (such, for instance, as may be seen in the north of Bavaria). The upper beds are, on the whole, more slaty than the lower ones, but still contain compact limestone bands, characterised by the usual fossils. In the neighbourhood of Basle, and in some parts of Wurtemberg, the lower part of the formation consists of a yellowish coloured limestone, alternating with thin bands and veins of gypsum, and contains a considerable quantity of rock-salt, differing in this respect from the contemporaneous formations in other districts. Lastly, the muschelkalk is occasionally a bituminous rock, and emits a fetid, disagreeable odour when rubbed or struck with a hammer.

(3.) The Keuper, the uppermost division of the Triassic system, is called by the French *marnes irisées*, and this name, translated into English (variegated marls), has frequently been applied to the upper members of the New red sandstone formation in our own country.

The group usually consists of a numerous series of mottled marls of a red, greenish grey, or blue colour, which pass into green marls, black slaty clays, and fine-grained sandstones. Throughout the series common rock-salt and gypsum are abundant, but the organic remains of animals are extremely rare. Of plants, however, a considerable number are preserved in some localities, and these indicate a wide departure from the flora of the carboniferous period, and, as well as the shells, seem to possess more analogies with the forms of life determined from the fossils of the secondary period, than with those common in the Palæozoic rocks.

CHAPTER XX.

FOSSILS OF THE NEW RED SANDSTONE, AND TRIASSIC SYSTEM.



GROUP OF FOSSIL SHELLS FROM THE MUSCHELKALK.*

The condition of the ancient seas and the adjacent land subsequent to the Palæozoic period, and while the sandstones and limestones of the Triassic system were being deposited, is not a little obscure, not only from the general rarity of fossils throughout the formation, but also because such as are found chiefly occur in the limestone, which is

* *a.* Myophoria vulgaris.
b. Avicula socialis.
c. Terebratula arculata.
d. T. vulgaris, *var.* elongata.
e. Spirifer fragilis.
f. Melania turritellaris.
g. Ammonites (*Ceratites*) nodosus.
h. Rhyncholites hirundo.
i. R. gaillardoti.

a local and always a subordinate member of the group. There is, however, sufficient proof that considerable change had taken place, and that a new era had commenced, in which reptiles were introduced, although rather in addition to than replacing the large Sauroid fish, so remarkable in the carboniferous rocks. Of the few fossils obtained from the sandstones, almost all, until lately, consisted of imperfect fragments of shells; but both England and Germany, as well as some other parts of the continent, now supply also the bones and teeth of reptilian animals of a very remarkable kind; and in many localities the marks of footsteps of these or other animals have been preserved in thin beds of marl, intervening between the strata of sandstone. The fossils of the Muschelkalk are numerous and varied, but they are, for the most part, peculiar to the stratum, and cannot be looked upon as characteristic of the whole Triassic group.

The flora of the period we are now considering hardly differs sufficiently from that of the coal-measures to require detailed description in this place. The fossil plants are chiefly found in the marly beds of the Keuper; they differ in specific character from those of the carboniferous system, and still more widely, perhaps, in the relative abundance of particular genera and families. The whole series of Stigmaria, Sigillaria, and Lepidodendron, are totally absent, and are replaced only by a few new ferns and several small equisetaceous plants; but the ferns are interesting, and they have been found occasionally with the marks of fructification. There is no deposit of true coal in the formation, and the perfect condition in which the more delicate parts of plants are sometimes preserved in the dark-coloured shales of the upper bed, indicates an alteration in the circumstances of deposit, the real extent of which it is by no

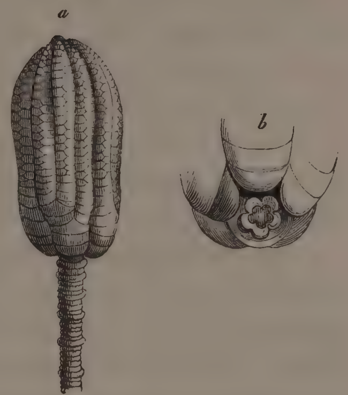
means easy to determine. Here, as in the overlying sandstones and shales of the Lias, plants of the *Zamia* tribe seem to have been more abundant than any others, unless, indeed, the frequent preservation of the remains of such plants is owing to their being less destructible than those of other natural families. These fossils are all of them much more common in the continental beds than in our own country.*

It is chiefly in the Muschelkalk that the fossil remains of animals are found, and they consist of encrinites and shells, together with various fragments of fishes and bones of reptiles. The muddy character of the limestone, and the preponderance of incoherent sandstone in the beds associated with it, seems to have been extremely unfavourable to the growth of coral, and organic remains of that kind are in consequence extremely rare: but these muddy bottoms, on which the coral animal could find no solid foundation, were, on the other hand, particularly favourable for the development of some of the radiated animals called *Encrinites*, of which mention has already been made in describing the fossils of the Carboniferous system. One species of these in particular, the *Encrinites moniliformis*, or lily-encrinite, is remarkable for the elegance of its form, and the singular beauty of its proportions. The form may be, in some measure, judged of by the woodcut annexed, or by the examination of fossil specimens, which are not rare; but we can only form an idea of the gracefulness and flexibility of the animal by considering the singular nature of its skeleton, which, at first sight, appears simple, but which, on careful investigation, will be found

* Sometimes, however, in the New red sandstone itself large fragments of silicified wood are found, one specimen of which, found in Warwickshire, is figured in the vignette at the end of this chapter.

to be made up of not less than 26,000 separate pieces of stone.*

The body of the lily-encrinite was supported on a long and nearly cylindrical column, attached to a rock or some hard substance at the bottom of the sea by an enlargement of its base. This column was made up of a vast number of joints, articulated one with another, and each having a central aperture, forming part of a hollow axis, which descended from the stomach of the animal to the base of the column.† On the summit of the column, which is five-sided, there are placed five small wedge-shaped plates, and these are surmounted by three similar series, each larger than the preceding, and so contrived as to include a central cavity, in which is contained the vital parts of the animal. From the uppermost plates pairs of columns arise, also having pentagonal bases; and each of these almost immediately branches off into two others. Thus it happens that, at a very short distance above the column, there are no less than twenty moveable arms, each of which is provided with a number of tentacles or fingers branching off from its side, and made up of a vast number of small joints, by means of which



ENCRINITES MONILIFORMIS.

Muschelkalk.

a. Side view, exhibiting the column and arms.
b. Base of the pelvis, showing the attachment of the column.

* Parkinson's Org. Rem., vol. 2. p. 180.

† See Chapter 26, in which the Apiocrinite of the Bradford clay is figured.

any food that may be floating within reach is readily caught, and carried to the mouth at the orifice of the stomach. This species of encrinite is characteristic of the muschelkalk, where fragments of it are found very frequently, although perfect specimens are rare.

The remains of Brachiopodous molluscs are not common in the Muschelkalk, and these animals seem to have required a different condition of the surface bottom of the sea, and probably deeper water than existed at the time and under the circumstances; but, on the other hand, various genera of the family "Ostraceæ," and, amongst others, the Avicula,* (*A. socialis*,) the Mytilus, Mya, &c. together with other genera, such as Pholodomya, &c., known to inhabit shallow water and the neighbourhood of land, seem to have been exceedingly abundant, and their remains are found in all parts of the formation. Several univalve shells also are found, and, from the general character of the fossils, there appears to have been, at the time of the deposition of the Muschelkalk, a condition of the sea much more nearly analogous to that which exists in the neighbourhood of our own shores, than is the case with any rocks of the Palæozoic series. Certain species of Nautilus were sufficiently common, and a number of other Cephalopodous animals existed, of which only the horny mandibles are found.† Of these we may assume, that they were in all probability soft, and, like some of the recent species, not provided with any shell or stony skeleton. There is, however, one Multilocular species greatly resembling the Ammonite, (*Ceratites nodosus*,) the sharp

* See the group of fossils characteristic of the Muschelkalk at the head of this chapter.

† These are called *Rhyncholites*, and two species are figured p. 296.

angles which mark the outline of each septum in the Goniatite being succeeded in this subgenus by a line much more complicated, and in which the indentations are curved, each of them in its curvature exhibiting a portion of a circle larger than a semicircle.

The remains of FISHES most abundant in the Muschelkalk, consist chiefly of the teeth and scales, those parts being the most indestructible, and therefore the least easily injured by long exposure after the death and decomposition of the animal. They are referred to several natural families whose remains are also found in other parts of the Secondary formations, and differ entirely from those of the Palæozoic strata. The most striking peculiarity indicated in their structure consists in the arrangement of a number of thick, round, flattened teeth, distributed over all parts of the palate, and adapted to crush with irresistible violence the shells of molluscous animals and crustaceans, and perhaps also to reduce to pulp the tougher and thicker of the sea-weeds.

It is in the strata which compose the Secondary series of formations that the remains of REPTILES are found in the greatest abundance and variety; and throughout the long period during which these strata were being deposited, reptilian animals appear to have been the most powerful, the most characteristic, and, with very few exceptions, the most highly organized of all the inhabitants of the earth. It will, therefore, be expedient now, at the commencement of our account of the fossil organic remains of vertebrata of the Secondary period, to allude more particularly to the class of reptiles, and the nature of the subdivisions within which the different extinct species have been included.

Reptiles were divided by Linnæus into only two orders, distinguished by the presence or absence of external feet; and the number of species referred to the class in his time being comparatively small, and their peculiarities not very strongly marked, except in a few instances, this arrangement was sufficiently convenient. Of late years, however, the examination of fossils, and the great variety of new species thus introduced, together with the remarkable departure from all ordinary types of structure exhibited by many of them, has enforced the necessity of a more definite and complete classification, which shall include in natural groups all the known species of these animals, as well those now existing as the numerous extinct ones characteristic of the Secondary and Tertiary formations. The science of Palæontology is indebted to Professor Owen for this, as for many other valuable improvements in classification,* all of which having been suggested by an accurate knowledge of anatomical detail, combined with sound general views, are of great value, and have been in almost every case received by Zoologists.

* It is, however, not only for his admirable general views of the classification of animals, but chiefly in the application of his unrivalled powers as a descriptive anatomist, that Palæontology is so greatly indebted to Prof. Owen. His account of the British Fossil Reptiles and Mammalia, prepared at the instance of the British Association, published in successive Reports of the Association, and now being republished with illustrations that have never been surpassed in beauty and accuracy, are, beyond all measure, the most valuable additions that have been made to Palæontology since the publication of the "Ossemens Fossiles." The singular acuteness of Prof. Owen's powers of observation, and his ready application of every kind of knowledge that can be brought to bear upon all departments of Palæontology, have tended so much to the advance of Geology, that it would be unjust to withhold in this place the tribute of admiration due to one who has so greatly distinguished himself, and so essentially advanced the true interests of science.

FIRST DIVISION. VERTEBRATA.

CLASS. III. REPTILIA.*

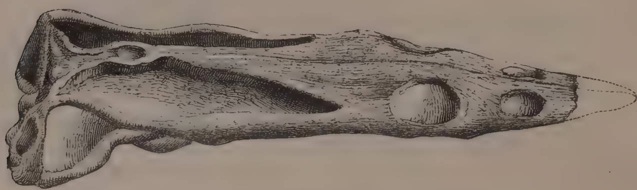
			Found fossil in
ORDER 1.	*DINOSAURIA*	(Land Saurians).	Oolites, Wealden.
„ 2.	*ENALIOSAURIA*	(Marine Saurians).	Muschelkalk, Lias, Oolites, Wealden, Cretaceous.
„ 3.	CROCODILIA	(Crocodiles, &c.).	Lias, Oolites, Wealden, Cretaceous, Tertiary.
„ 4.	LACERTILIA	(Lizards).	Mag. Limestone, New red sandstone, Cretaceous.
„ 5.	*PTEROSAURIA*	(Flying Saurians).	Lias, Oolites, Wealden.
„ 6.	CHELONIA	(Tortoises, &c.).	New red sandstone, Oolites, Wealden, Cretaceous, Tertiary.
„ 7.	OPHIDIA	(Serpents).	Tertiary.
„ 8.	BATRACHIA	(Frogs, &c.).	N. R. sandstone, Tertiary.

The reptiles whose remains are found in the New red sandstone of England, or in the contemporaneous beds of the Triassic system on the Continent, consist of several species of the order of marine saurians (*Enaliosauria*), which are confined to the Muschelkalk, together with a singular genus of Lacertian reptiles, called *Rhynchosaurus*, and the bones of several species still more remarkable, referred to the order Batrachia: these latter being found chiefly in the lower part of the New red sandstone in Warwickshire and Lancashire, and in the Bunter sandstein, or lower part of the Triassic series, in Germany.

It is not necessary to dwell at any length on the peculiarities of structure of the *Nothosaurus* or the other saurians

* All the species referred to those orders of which the name is printed in Italics, have only been found in a fossil state, and the geological distribution of each order is marked, so as to give some notion of their relative extent. Not less than twenty-seven new genera have been added to the list of reptiles from the examination of British fossils only; and most of these are so remarkable, and many of the species have attained such large dimensions, as to render it impossible that they should have escaped observation, did any of them at present exist on the globe.

of the Muschelkalk, because they are chiefly interesting to the Comparative Anatomist for the analogies they exhibit with the Plesiosaurus,—another Enaliosaurian genus,



CRANIUM OF NOTHOSAURUS MIRABILIS.

occurring in the Lias, and to be described in a subsequent chapter. The remains of the Nothosaurus have not been found in England, nor are they common, except in a very fragmentary state, in any of the continental beds. The beautiful sculpturing of the cranium, however, and the large comparative size of the extremities, seem to approximate this genus to the crocodileans, and to indicate a link connecting the latter order with the marine saurians.

One of the most curious and interesting of all the Lacertian reptiles hitherto described is the extinct genus *Rhynchosaurus*, recently established by Professor Owen from a skull and other fragments found in the lower beds of the New red sandstone near Shrewsbury. The footmarks of a small animal have also been observed in the sandstones of the same quarry from which the fossil bones were taken; and from their correspondence in size, and their being the only footprints found in the quarry, they are supposed to have been left by the passage of this little reptile over the strata, which must then have been the sands of a sea shore.

The skull of the Rhynchosaurus is very different in shape from the skull of any other Lacertian either recent or

extinct, and resembles more that of a bird, or the hawk's-bill turtle than that of a lizard, the resemblance being increased by the apparent absence of teeth. This peculiarity is caused by the intermaxillary bones converging towards each other from behind forwards, and being in close contact where they form the singular curved projecting beak. Although the actual condition of the masticatory organs cannot be ascertained, yet from the fact of the lower jaw being in undisturbed articulation with the head, and that the absence of a coronoid process (conspicuously developed in all existing lizards,) corresponds with the unarmed condition of the jaw, the resemblance which the Rhynchosaurus bears in other respects to the turtles would seem to indicate, that the correspondence extended also to their toothless condition.* Professor Owen observes, that the resemblance of the mouth to the compressed beak of certain sea-birds, renders it probable that the Rhynchosaurus may have had its jaws encased by a bony sheath.

Some bones of the extremities have been found in the same quarry as that from which the skull just described was obtained, and they have been referred to an animal of the same genus. In these a singular approximation in form may be observed to the corresponding bones in the large extinct species of land reptiles of the Oolitic period, and although many important parts are still wanting to enable the Comparative Anatomist to reconstruct the entire animal, it appears, from the fragments that remain, to have been provided with an apparatus adapted for locomotion on land, of a very different character from that of most lizards; and the foot seems to have had a hinder toe directed back-

* See Prof. Owen's Memoir; Trans. of Cam. Phil. Soc. vol. vii. p. 355; and Report on British Fossil Reptiles; Proceedings of Brit. Assoc. for 1841, p. 150.

wards, as is the case with birds, and indications of which are seen in the footprints already alluded to.

But singular and anomalous as the Rhynchosaurus and the Nothosaurus may have been, they did not depart so widely from the structure and proportions of existing species of Reptiles as the one which remains to be described, —the *Labyrinthodon*. And this latter genus is the more interesting as it has tended to illustrate the nature of certain animals, of which the only thing known with certainty is, that they inhabited the sea coasts during the deposit of the New red sandstone strata, and that, in moving about over the sands and marls of the sea shore, the impressions of their footsteps in the mud or sand were sometimes retained, and have been perfectly preserved to the present time.*

It may appear at first sight, that nothing can be more fleeting, or less likely to be handed down to future ages among the *fossils* of a bed of sandstone, than the casts of the impressions of the footsteps of an animal who may by chance have walked over that bed when it existed in the condition of loose sand forming a sea shore. A little consideration, however, will show, that this is, in fact, a very possible occurrence: as, if the wet sand should be immediately covered up with a thin coating of marl, and another layer of sand be superimposed, such an impression will be

* The occurrence of ripple marks, such as are seen at low water on the flat part of a sea-beach formed of fine sand, has been observed in many sandstones, more especially in those of the New red system, and of the Weald. It is well known that, if pure water passes over another portion of water in which fine sand is held in suspension, there will be ripples produced, of which the marks do not disappear when the cause ceases to act; so that, if after their formation at the bottom of a shallow sea, some adjacent river or current deposit upon them the mud which it holds in suspension, the former marks will be preserved, and any footprints of animals which had passed over would also be perpetuated, and new ripple marks with other footprints would soon appear above them.

FOOTMARKS OF ANIMALS IN THE NEW RED SANDSTONE.

permanently preserved. In after ages, also, when the soft sands have become sandstones, and are elevated above their former level, the stone splits asunder wherever a layer of a different material occurs; and thus it happens, that the casts of the footsteps may be preserved and exhibited, although all other traces of the former existence of the animal are lost.

At any rate such markings have long been known to exist in various parts of the New red sandstone, and chiefly in certain beds quarried near Liverpool, in others at Hildburghausen in Saxony, and again in other beds of sandstone supposed to be of the same date in Connecticut in the United States of America. Those found in Europe consist partly of the footsteps of small animals, supposed to be tortoises and turtles, but contain, also, amongst them, others belonging to a much larger animal,

and differing entirely in shape and proportions from such as would be left by any known quadruped or reptile. The American specimens have been referred by Dr. Hitchcock to large birds.

The larger footmarks found impressed on the marly sandstones of the New red sandstone in Europe, bear a singular resemblance to the impression that would be made by the palm and expanded fingers and thumb of the human hand, and for that reason the name *Chirotherium* (χεὶρ, *a hand*, θηρίον, *a beast*,) was proposed to designate the unknown animal by which they had been produced. The dimensions are various; but in all cases the prints of what appear to have been the hind feet are considerably larger than those of the fore feet, so much so, indeed, that in one well preserved slab containing several impressions, the former measures eight inches by five, and the latter not more than four inches by three. In this specimen the print of the fore foot is not more than an inch and a half in advance of that of the hinder one, although the distance between two successive positions of the same foot, or the length of a pace of the animal, is fourteen inches. It therefore appears, that the animal must have had its posterior extremities both much larger and much longer than the anterior; but this peculiarity it possessed in common with many existing species, such as the frog, the kangaroo, &c.; and beyond this and certain appearances in the sandstone, as if a tail had been dragged behind the animal, in some sets of footprints, but not in others, there is nothing to suggest to the Comparative Anatomist any idea of even the class of vertebrata to which the animal should be referred.

Within the last few years, however, certain fragments of bone have been found in some of the quarries of New red

sandstone, of the same age as those in which the footprints occur, and several teeth; the careful examination of which by Professor Owen has given great interest to these singular fossils, and may almost be said to have explained the nature of the animal of which such indications have been preserved.*

Before Professor Owen had the opportunity of examining these remains, several teeth found in the Keuper of Wurtemberg had been referred to new genera of Saurians, under the names *Mastodonsaurus*, and *Phytosaurus*; but on placing thin slices of similar teeth under a powerful microscope, they were found to possess a remarkably complicated structure, approximating the animal rather to the fishes than the Saurian reptiles. Shortly after this, several fragments of bones from the same locality were found, and came under the observation of Professor Owen, who was thus enabled to arrive at more satisfactory conclusions, and to describe the structure of several species (amounting in the whole to five), all of which he referred to the same genus, including in it also the supposed Saurians of Wurtemberg. This genus he named *Labyrinthodon,* in consequence of the labyrinthine appearance observable in the minute structure of the teeth. I will endeavour to give, in a few words, the results of the investigations upon which the genus was founded and the different species determined.

In the first place it appears, that the animal must have

* For all detailed description of this and other fossil reptiles, whose remains are found in our own country, I must refer the reader to Professor Owen's elaborate and valuable papers on the subject already referred to. Almost the whole account that I shall be enabled to give of most of the reptiles of the Secondary period will have been derived from his descriptions; and my chief object is, to give an idea of the results he has arrived at, in a manner sufficiently intelligible to the general reader.

belonged to the Batrachian order of reptiles, and that the different species varied considerably in size; the smallest hitherto determined much exceeding in dimensions the largest living species of the same order, but the larger ones actually measuring several feet in length.

The cranium of the Labyrinthodon was broad, depressed, and flattened, like that of the alligator, the outer surface being also strongly sculptured: the condition of the nasal cavity indicates a resemblance to the Saurians in the mode of respiration, and although the modifications of the jaws prove this extinct genus to have been essentially Batrachian, it must in many points, especially in the proportions of the head, have approximated to the higher Saurians; while in others, such as the biconcave structure of the vertebræ, and the mode in which the teeth were reproduced, and subsequently became fixed to the bone, it presents affinities scarcely less remarkable to fishes. The arrangement of the teeth is illustrative of the Batrachian character, one row of small teeth extending transversely across the anterior extremity of the vomerine bones, and another longitudinal row being continued backwards along the exterior margin of the palatal bone.

The extremities offer analogies partly with the Batrachians, and partly with the Crocodilean tribe, the principal resemblance to the latter being seen in some bones of the pelvis.

With regard to the proportions and dimensions of this singular genus, there has been found one fragment of a lower jaw between nine and ten inches in length, and corresponding to the same part in a crocodile six or seven feet long; but fragments of bones of hinder extremities found in the same quarry, and referrible to the same species, are as large as those of a crocodile four times

that length. Now if, as is probable, these belonged to the same individual, the hinder extremities must have been of a magnitude utterly disproportionate, when compared with those of existing Saurians; but of very fair proportions, when considered with reference to some of the living tail-less Batrachians.*

It appears then, that there are found in the New red sandstone certain footprints, indicating an animal remarkable for the disproportionate magnitude of its posterior extremities, and also for the singular shape of the foot. In the beds of the same formation are found also the teeth and bones of a Batrachian reptile, of dimensions and proportions sufficient to produce the footprints, and of which the structure of the teeth and of the bones of the extremities is remarkable and anomalous. Perhaps it is hardly too much to assume, that the animal is discovered whose footsteps have excited so much curiosity, and that the Chirotherium is the same as the Labyrinthodon.

The supposed footsteps of birds in the New red sandstone of North America, being unaccompanied as yet by any bones, it is hardly safe to speculate as to their nature. Many of them seem to be those of wading birds of ordinary dimensions; the marks of three toes being distinct, and that of the fourth, or hinder toe, generally wanting; others are more remarkable, and seem to have been made by birds of very gigantic proportions, the impressions being as much as fifteen inches in length, and the distance of the impressions asunder, or the length of the pace, not less than from four to six feet.†

Mr. Lyell has lately examined the locality in which these impressions are found, and concurs entirely in the

* Prof. Owen's Report, *ante cit.* p. 188.

† American Journal of Science and Arts, for January, 1836.

views of Professor Hitchcock, as above expressed. The sandstones being separated by several thin laminæ of green shale are very favourably circumstanced for the perfect preservation of the impressions; and the foot-prints here, as in other cases, are accompanied by many other appearances, such as the ripple-marks commonly seen on a sandy shore, at low water; casts of cracks in the sandy clay; and, not unfrequently, peculiar rounded marks, which have been supposed, by Dr. Buckland, to have been produced by the dropping of heavy rain on the soft marls by the sea-side.*

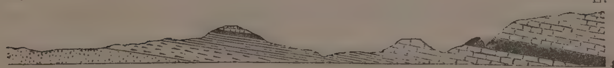
* It may be worth while to mention, with reference to the large proportions of the footmarks of birds found in America, that the remains of Struthious birds (birds allied to the ostrich) have been found in a semi-fossil state in New Zealand, the feet of which are sufficiently large to have produced such marks. The animal to which these remains belonged is calculated by Professor Owen to have attained the height of at least ten feet, and I shall have occasion to allude to it again when speaking of the fossils of the superficial deposits in which it has been discovered.

FOSSIL TREE.

New Red Sandstone of Warwickshire.

CHAPTER XXI.

THE ROCKS OF THE LIAS FORMATION.



SECTION FROM THE SEVERN TO THE COTTESWOLD HILLS.*

The formation of the "Lias," (so called from a barbarous provincial word, supposed to be a corruption of *layers*, and to allude to the riband-like appearance of the rock when seen in section,) consists of strata, in which an argillaceous character predominates throughout, but which are also remarkable for a quantity of calcareous matter mingled with the clay, and forming occasional bands of argillaceous limestone. A few beds of sand also alternate with the clay and marl, and are sometimes mixed with the latter, forming a marly sandstone of a white or greenish colour.

Considered as a formation, the Lias in England may be traced in a north-easterly direction from Lyme Regis, on the coast of Dorsetshire, (where it is displayed along a line of cliffs extending for about four miles,) to the coast of Yorkshire, near Whitby. It consists throughout of the same beds of marly limestone, and, from Gloucester, northwards, is remarkably regular, presenting an average and nearly uniform breadth of about six miles, being covered

* 4. Upper Lias. 2. Lower Lias Shale.
3. Marlstone. 1. Lower Lias limestone.

up on the east by the escarpment of the Oolites, and the New red sandstone coming out from beneath it on the west. Its thickness is about 600 feet; it is little disturbed, and has a regular dip, being conformable to the underlying and overlying strata, except where it comes in contact with the mountain limestone in Glamorganshire and Somersetshire, and is partially affected by the faults and disturbances of those districts.

It forms for the most part broad and level plains, at the foot of the Oolitic hills, only a slight escarpment being visible in the southern counties, although this becomes more prominent on the borders of Nottinghamshire and Leicestershire, where it forms a well-marked range, known as the Wold hills. It also occurs occasionally on the brow of tolerably steep escarpments in the Mendip hills; but its maximum of elevation falls short of 500 feet above the level of the sea.*

The sub-divisions of the Lias are different in different parts of England; but on the whole, there seem to be four principal members, referred to in the diagram at the head of this chapter.

The lowest portion of the Liassic system seems to consist of a very thin bed, in some places entirely made up of the fragments of fossil bodies, (chiefly the remains of fish,) but sometimes passing into a white micaceous sandstone, still recognisable as the same bed, although without fossils.† This bed was first observed, underlying a small patch of Lias, near the town of Aust (situated on the left bank of

* Conybeare and Phillips, p. 276.

† With regard to the nature of these fossils, Prof. Agassiz, in his catalogue of Placoid fish, in the 3rd vol. of the *Poissons Fossiles,* enumerates not less than fifteen species, found chiefly in the bone bed, at Aust, and all appearing to possess rather a Triassic, than a Liassic character. Notwithstanding this, however, the bed can only be looked on as the commencement of the deposits of the newer period, or perhaps, a passage from the one system into the other.

the Severn, nearly opposite the mouth of the Wye); but it has since been recognised at Axmouth, in Devonshire, and in other parts of England farther north, having a total range of upwards of 100 miles. It is rarely more than two or three inches in thickness, but invariably occupies the same geological position, and is for the most part so exclusively composed of organic remains, that a long period must have been required for its formation.

It is chiefly in Gloucestershire and Worcestershire that the passage of the New red sandstone into the lower Lias shale is marked by the presence of calcareous flagstones, "the lower Lias limestones;" and these usually alternate with laminated shales, the whole together forming the first and lowest deposits of Lias. These beds contain the characteristic fossils of the formation, and are not traceable to any considerable distance, either northward or southward.

The great mass of the lower division of the Lias, in the middle of England, consists, however, of thick beds of dark-coloured and finely-laminated shale, in which occur occasional calcareous bands and concretions. These form the base of the series, and graduate downwards into a whitish sandstone, belonging to the uppermost beds of the New red system. The transition is different again in the south of England; at Lyme Regis, marls of a light bluish colour represent the upper beds of the New red sandstone and pass into the Lias limestone by a succession of dark slaty marls, which are succeeded by a number of grey calcareous beds, and these again by other slaty marls of the upper series. The marlstone and upper Lias shales are not present in this part of the deposit in their ordinary form.

The principal locality of the middle beds of the Lias is the neighbourhood of Cheltenham, where the marlstone of Dumbleton Hill is crowded with interesting organic re-

mains. It is made up of alternating layers of coloured clays and sands, which are occasionally calcareous, and of beds of impure limestone.

This part of the series is also represented in the north of England, where it has an average thickness of about 130 feet, and consists of sandy shales, of which the upper portions are distinguished by the presence of several bands of argillaceous irony nodules.

The upper Lias, or Alum shale, is best seen at Whitby, and on the Yorkshire coast, and it attains there a considerable thickness. It consists of three distinct parts: the lower division including soft shales, extremely fossiliferous, which are separated from the uppermost series, also composed of incoherent slaty beds, by an intermediate stratum of hard shale, about thirty feet thick, containing a quantity of the mineral called *jet*, and also, occasionally, large fragments of the bituminised wood of coniferous trees. The jet itself is but a peculiar form of carbon, and there can be little doubt that it is of organic origin. It is in the upper shales of the Lias, both on the coast of Yorkshire and at Lyme Regis, that there have been found the most remarkable and interesting of those fossil remains of extinct animals, for which the formation is so celebrated. The presence of alternate bands of tolerably hard limestone and soft shale, is usually characteristic of the Lias in the different parts of England, where it is most developed. The dark bluish grey-colour, united with this singular riband-like structure, is more particularly remarkable in the upper beds of the formation, and is well seen at Lyme Regis, Whitby, and Barrow-upon-Soar, in Leicestershire.

On the continent of Europe the Lias is also found, and is characterised by nearly the same lithological character and fossils as in our own country. It is there also separated

readily into three parts; but these are somewhat different from the groups described above, the lower one being often more arenaceous, and the middle one more decidedly calcareous, than can be said of the lower and middle divisions in any part of England: the upper beds are, however, very similar to those at Whitby and Lyme Regis, being made up of soft and incoherent marls, which pass into nearly similar strata of the Lower Oolitic series.

The passage of the New red sandstone into the Lias is very gradual and almost indeterminate in some parts of the Continent, and appears, indeed, occasionally to be more perfect than the passage upwards into the Oolites. An interesting instance of this occurs in the south of Belgium, where the ordinary sandstones of the Keuper are succeeded by another of an intermediate character, which is white, micaceous, and quartzose, and occasionally mixed with fragments of rolled argillaceous and siliceous rocks of much older date. This conglomerate forms an admirable building-stone, and occupies prominent escarpments, which have been taken advantage of in laying out the fortifications of Luxemburg, one of the strongest fortresses in Europe. The town of Luxemburg is situated at the foot of one of these escarpments; and the traveller may approach within a few yards of it before discovering that he is on the brow of a precipitous and lofty cliff, stretching along to a considerable distance, and only to be descended by roads cut in zig-zag lines on its steep face.

The bed just described passes upwards, sometimes into sandy, and occasionally into calcareous marls, and unquestionably belongs to the Liassic system, although so different in mineral character from the upper beds. It is succeeded by a marly limestone, called by foreign Geologists "Gryphite limestone," in consequence of its abounding with a

peculiar and characteristic fossil, (*Gryphæa incurva*,)* found also in the Lower lias shale of England. The Gryphite limestone is marly and of a light bluish or greyish colour. It is sometimes crowded with fossils, and sometimes totally without them.

The upper marls are the most constant and invariable of the continental Liassic series, and are always present, except where the lower sandstones are very much developed. Like the beds of the same age in England, they are of a brown, grey, or bluish colour, and are, more or less, mixed with clay; but they are sometimes sandy, and often alternate with shales, in which nodules of calcareous matter abound,—the nodules when burnt forming an admirable cement. In other cases the marls are black, bituminous, and fetid, being loaded with carbonaceous matter, doubtless of organic origin.

The Lias is extensively spread throughout Europe, being found in both the French and Swiss portions of the Jura chain, and in Wurtemburg, Westphalia, Hanover, and the northern part of Bavaria. In the neighbourhood of Banz, in the latter country, noble sections are exhibited, the Lias being separated into no less than forty-six bands, each of which is distinguished by peculiar mineral or zoological characters, and the whole series being based upon the Keuper sandstones, and overlaid by the sandstone of the inferior Oolite. The lower beds of this great series consist of shale and sandstone, containing the Gryphite limestone; the middle mass is characterised by its slaty clay and alum shale, containing the fossils common in our own country, while the upper beds are chiefly composed of bituminous slaty marl, alternating with Posidonia limestone.

Besides these localities the Lias formation is met with in

* See the group of fossils figured at the commencement of the next chapter.

the Alps, where it is occasionally in contact with the granite, and where it contains several metallic ores, such as galena, calamine, oxide of chrome, &c., distributed through the disturbed and altered strata, both in veins and masses.* It will be seen afterwards, that in these disturbed districts, the Lias forms, as elsewhere, a continuous series with the Oolites, which are rarely absent when the Lias is extensively developed.

Liassic fossils have been found in Northern India, and the province of Bundelkund would seem to exhibit a somewhat considerable development of this formation. Its general geological character is said to correspond with that of the same bed in England, but it contains light-coloured and compact varieties, which have been found capable of being used for lithographic purposes. At present, however, although several species of Ammonites, and some other fossils, have been determined,† there is not sufficient evidence on which to found any important generalisations.

It is not easy to say at present how far this bed extends, or how completely it can be depended on as a base line from which to determine other and less known formations.

There is reason to doubt if the New red sandstone or its equivalent, in North America, is covered up with any newer deposit so old as the Lias, but this bed is probably represented in some parts of South America.

* D'Aubuisson, par Burat, vol. 2, p. 432.

† See figures of these fossils, Asiatic Researches, vol. xviii., opposite p. 114.

CHAPTER XXII.

THE FOSSILS OF THE LIAS.—INVERTEBRATA.

GROUP OF LIAS FOSSILS.*

The Lias is, perhaps, of all formations that which is the most rich in organic remains, and from the nature of the strata, and the facility with which they are acted on by the weather, new surfaces of rock, and therefore fresh fossils, are constantly exposed, wherever the strata crop out and appear either in a sea-cliff, or along the line of a low escarpment. It happens too that, on the whole, the alternating

* *a.* Pachyodon listeri. Stutch.
b. Cucullæa elongata. Sow.
c. Hippopodium ponderosum. Sow.
d. Gervillia. u. s.
e. Plagiostoma giganteum. Sow. (*Young.*)
f. Gryphæa incurva. Sow.
g. Terebratula subserrata.
h. Spirifer verrucosus. Von Buch.
i. Pleurotomaria anglica. Sow.
k. Nautilus decussatus.
l. Ammonites colabratus.

limestones and argillaceous shales of the formation are admirably well adapted both for preserving and exhibiting the fragments of organic matter deposited in them; and not only the harder and less perishable, but also occasionally the impressions of the softer parts both of animals and vegetables are retained with great accuracy. These markings seem to have been left upon a calcareous mud, now hardened into the Lias limestone or shale, but which, at the period when the deposit was going on, formed the bottom of a shallow sea, at no very great distance from the land, or at least not far from some island clothed with vegetation, and inhabited occasionally by the amphibious and other reptiles whose remains characterise the various strata.

At any rate it so happens that the Lias abounds with organic remains, presenting new and interesting species of almost all the great natural families. We find, for instance, Radiata, Mollusca, (and amongst them, more especially, the Cephalopodous molluscs,) Fish, and Reptiles, each represented by various species, exhibiting to the Palæontologist and the Comparative Anatomist the most singular forms, and the most striking analogies, as well as differences of structure.

The Fossil botany of the Lias—to proceed in the same order that has hitherto been followed in speaking of the fossils of other formations—is not so different from that of the underlying or overlying strata as to require any detailed account. The existence of true coniferous wood at the period of this deposit is, however, clearly and satisfactorily made out by microscopic examination; and various fragments, in which the structure is distinct, have been called by Dr. Lindley, *Peuce*, a factitious genus, proposed only for present convenience, and as a means of distinguishing the

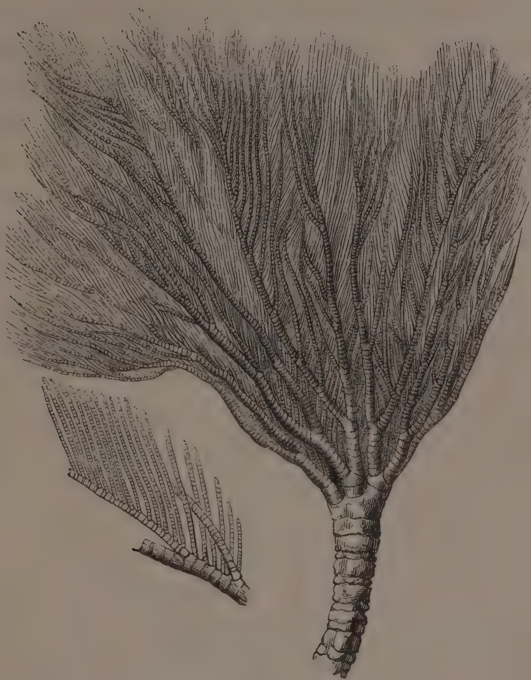
true coniferous wood from those numerous fossils in which there is only an approximation to coniferous structure, and which have been called by the same author, *Pinites*.

The fossil leaves of plants allied to Zamia are also sufficiently common in the Lias, both of England and the Continent, and more especially in the sandy beds near Whitby. They belong to a natural family, which, with ferns, includes almost the whole number of species found in the formations of the Secondary period, and they thus possess considerable interest, more especially as they differ entirely in generic character from any plant found in the strata of the Palæozoic period.*

The absence of corals in the Lias, as in the Muschelkalk, would seem to be owing to the argillaceous matter deposited with the carbonate of lime, and with which the calcareous strata of these formations abound; but the abundance of Crinoidal remains more than makes up for this deficiency, as the Lias is especially rich in radiated animals, several genera being represented by species of great beauty and interest. Of the whole number of these none is more remarkable than the *Pentacrinites*, whose fragments are so abundant, that there exist actual beds some inches in thickness entirely made up of them; and the remains are occasionally so complete, that every part of their stony skeleton may be examined with the utmost minuteness, and the habits of the animal traced, by considering the circumstances under which the fossil occurs.

The Pentacrinite differs from the Encrinite (see p. 299) in several important characters: the stem, for instance, instead of being round is (as the name imports) pentagonal or five-sided; innumerable branches arise from this stem; the arms are given off from it in a far more complicated

* See the account of this genus in greater detail in Chapter 26.



PENTACRINITES. SUBANGULARIS. MILL.*
(*Lyme Regis.*)

manner than in other Encrinites; the pouch is entirely different and covered with a tough membrane; and the number of the parts of which the skeleton is composed is so much greater that, in some species, it cannot be less than 150,000.

The animal provided with this singular and complicated apparatus, is supposed by Dr. Buckland,† to have been capable of withdrawing itself readily from any substance to which it was attached, and after floating about in search of a new and more convenient resting-place fixing

* The smaller figure represents a portion of one of the branching arms, of the actual size; and exhibits the manner in which the last columns or fingers are given off.

† Bridgewater Treatise, vol. i. p. 436.

itself again, usually upon the lower surface of some floating piece of timber. This notion is probably correct, for the long stem does not enlarge towards the base, (as in the Encrinite,) and is not possessed of any solid root, by which it could have been fixed permanently to a mass of rock. It is also known, that whenever great masses of Pentacrinites are found together, they have occupied the *lower* surface of a bed, which is now lignite, and to portions of which they are sometimes fastened.*

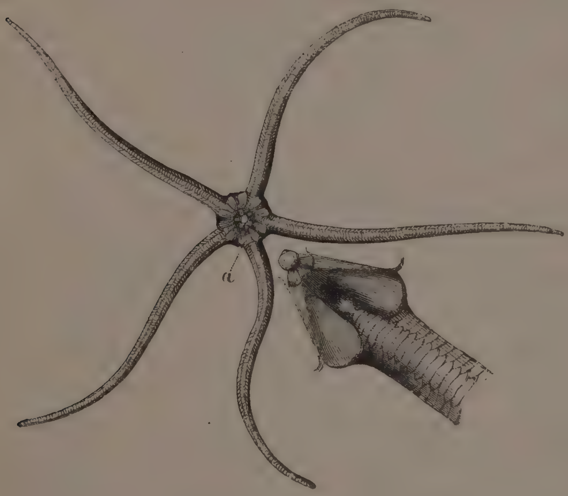
The stomach of the Pentacrinite formed a funnel-shaped pouch of considerable size, composed of contractile membrane, and covered externally with many hundred minute calcareous plates of an angular shape; it was terminated at the apex by a small aperture, susceptible of elongation and becoming then a proboscis for taking hold of food, brought within its reach by the arms and fingers. It is placed in the centre of the body, on the summit of the column, and surrounded by the arms.

The column to which the stomach and arms are attached resembles that of the Encrinite, except in the five-sided shape of the joints and the number of short columns diverging from it along its whole length, the use of which it is not easy to guess at, unless, indeed, the animal multiplied itself in this way. These branches are given off from each of the largest joints of the column, and they consist of as many as from fifty to a hundred pieces each.

Lastly, the arms which rise from the five stony plates

* There is an existing genus in which the young animal singularly resembles a Pentacrinite, being provided with a stem, which it loses at a certain period of its growth, and then becomes a free swimming *Comatula*. From a careful examination of this interesting recent animal, there is no doubt that it has a perfect command over all parts of its flexible stony column, and can readily move its body and arms in every direction in search of food, and, perhaps, also yield without injury to the course of a rapid current or the fury of a storm, should the fragment, to which it is for the time attached, be exposed to such accidents. See Forbes' British Star Fishes, p. 11.

enclosing the body, are almost immediately divided and subdivided after they have left the pouch, and the subdivisions soon become so exceedingly numerous as not to be counted without difficulty: each arm, however, is provided with numerous tentacula, called fingers, every one of which is armed with a small tubercle or hook, the form varying in every instance, but evidently intended to serve as an organ of prehension. The arms and fingers, when expanded, must have formed in this way a net of considerable magnitude, and of far greater capacity than that of any other of the Encrinital animals.



OPHIODERMA EGERTONI. BROD.*

(*Whitby.*)

But the Pentacrinite was not the only one of the radiata of the Lias deserving special notice. Several beautiful specimens of a genus, nearly allied to Ophiura, have been found in one of the greenish sandstones of the Lias

* A portion of one of the arms, near its attachment at (a), is represented of a larger size in the detached figure.

near Lyme Regis, and also at Whitby, and I have given a figure of one of these from the Cambridge Museum. The animal could scarcely have differed in any important point from existing species, and similar remains of other species are found throughout the Oolites.

The fossil remains of various animals inhabiting bivalve shells are very numerous in all parts of the Lias, and several of those most characteristic are figured at the commencement of this chapter (see p. 320). The general appearance of the whole group, and also of the univalve shells, (the remains of Gasteropodous molluscs,) shows a considerably nearer approximation to the existing condition of the seas than is indicated by the Muschelkalk fossils; and this notwithstanding the wide differences which we shall presently find distinguishing the animals of higher organization from any recent species.

The condition of the Brachiopoda of the Lias is also interesting, at least three species of the genus *Spirifer* characterising the formation. This genus, never yet found in any formation newer than the Lias, thus forms a link connecting, as it were, the older rocks, where it is exceedingly abundant, with those of the Secondary period. The Terebratulæ of the Lias are numerous, but do not call for any especial notice in this place; and the same must be said of the univalve shells, with the exception of the Cephalopoda.

As there is scarcely any formation in which certain genera* referred to this latter order (Cephalopoda) are more remarkably preserved, or more abundant than the

* The following is a numerical list of the Cephalopoda found fossil in the Liassic beds in our own country. It is deduced from Mr. Morris's recently published "Catalogue of British Fossils."

Ammonites	69	Nautilus	5
Belemnites	12	Onychoteuthis	1

Lias, it will be proper here to describe, in some little detail, the probable nature and habits of one at least of the extinct genera referred to it, and of which many species are abundantly distributed through the formation.

The varieties of form, and the trifling although invariable peculiarities of structure, that distinguish the shells of those Cephalopoda allied to the Nautilus, and found fossil in rocks of the Palæozoic period and in the Muschelkalk, have been already sufficiently enlarged upon; but it remains still to describe another genus, the Ammonites, of which, so far as the form of the septa is concerned, a sufficient notion may be obtained by referring to the annexed engraving, but which contains a vast number of species, which are more widely spread and more abundant than those of any other genus of animals inhabiting multilocular shells.

AMMONITES HETEROPHYLLUS. Sow.
(*Whitby.*)

The peculiarities by which the Ammonite is distinguished from allied genera have reference, partly to the

substance of shell itself, to the relative proportion of the outer chamber, the singular form of the aperture, (traceable, however, only in the few instances in which that part has been perfectly preserved,) and also to the remarkable bosses and tubercles with which many species are adorned, and which have been supposed to mark specific differences. They relate besides to the complicated form of the wall of separation between the chambers, from which specific differences have been deduced; and, lastly, they are derived from the position of the siphuncle, (one of the chief generic distinctions,) and its magnitude in proportion to that of the shell.

In the first place then, with regard to the external form and proportions of the shell, it must be observed, that in the Ammonite the shell is usually flatter, and the whorls rounder, and more numerous, than in the Nautilus. The outer whorls also very rarely entirely enclose the rest, but are often, on the other hand, merely placed in contact, like those of the common fresh-water *Planorbis*, a genus which some of the Ammonites very nearly approach in external form, although they are absolutely and entirely different in all other respects. The shell of the Ammonite is usually thin, the last chamber (that in which the animal lived) occupies two-thirds, or more, of an entire whorl; and the aperture, when the specimen is sufficiently well-preserved, is found to be very singular, and probably variable both in form and structure; but this part appears to have been extremely thin and fragile, as the rarity of its preservation amongst the innumerable specimens of Ammonites in all Secondary formations might lead one to expect. In the Lias, abundant as these fossils are, no perfect specimens of the termination have, I believe, yet occurred; but the complete

shell has been met with in some of the clays and fine limestones of the Oolitic group which will render it necessary again to allude to this subject.

To make up, apparently, for the thinness of the shell, and to give additional strength without considerably increasing the weight, the greater number of the known species of Ammonites are ribbed and covered with tubercles, which, considering the shell as a continuous arch coiled round itself, serve the purpose of transverse arches and domes. The external surface was greatly strengthened by such mechanical contrivances.

And first, the introduction of ribs, distributed over the surface of the shell transversely to its axis, produces an effect in strengthening the arch which corresponds to the introduction of fluted metal, often made use of in mechanics, when the greatest strength requires to be combined with the smallest weight of material; and this structure Dr. Buckland has illustrated by referring to the application of thin plates of corrugated iron, sometimes employed in the construction of roofs, the corrugations supplying the place and combining the strength of beams and rafters.* Additional strength is also gained by the bosses, or elevations of part of the ribbed surface into dome-shaped tubercles, for these, like the vaultings in architecture, give strength to the surface to be supported, and are, therefore, usually placed at those parts of the external shell, beneath which there is no immediate support from the internal transverse plates or walls, which we have next to describe.

It is, perhaps, principally in the arrangement and construction of these internal walls of separation between each two of the empty chambers, that mechanical contrivance

* Bridg. Treat. vol. i. p. 340.

in the Ammonite is carried to its height; but the contrivance is one of a very simple kind, and consists in causing the extremities of the walls, where they meet the shell, to deviate from a simple line into a variety of ramifications and undulating sutures. "Nothing can be more beautiful," observes Dr. Buckland, "than the sinuous winding of these sutures in many species at their union with the exterior shell, adorning it with a succession of most graceful forms, resembling festoons of foliage and elegant embroidery; and when these thin septa are converted (as they sometimes are) into iron pyrites, the edges appear like golden filigrane work, meandering amid the pellucid spar that fills the chambers of the shell." *

The advantage of this contrivance in a mechanical sense is undoubtedly very great; and its relative value in the Nautilus and Ammonite may be understood, if the reader will consider that, in the first place, the chief effect of the septa in both genera is, to divide the large vacant space of the uninhabited part of the shell into a number of small chambers, each of which is independent of the rest; and, also, in the next place, that the power of resistance, or strength of the shell, will vary, *cæteris paribus*, according to the number of points supported within a given space, and, therefore, according as the wall meets the shell in a longer and more sinuous line. In the Nautilus, the septum being a plane surface, or nearly so, the number of points of the exterior shell supported is, therefore, the smallest possible; but, on the other hand, in the Ammonite, in consequence of the wavy outline of the septum, this number is very much greater, and in some species (more

* Bridgewater Treatise, vol. i. p. 347. See also *ante*, p. 327.

especially that one which has been selected for illustration, and which is of large size, has a thin shell, and is not greatly defended with ribs or bosses,) this complication is so extreme, that the whole surface of the shell is covered with the lines of intersection of the septum, or, in other words, with points supported from within.*

The position of the siphuncle is the last, although, perhaps, the most important peculiarity of the Ammonite tribe which I shall speak of in this chapter. It is in all cases dorsal, or situated quite on the outer margin of the shell, and in this respect differs entirely from the Nautilus and Clymene, but resembles the Goniatite and Ceratite. The siphuncle is usually small, and not unfrequently is quite exterior to the shell, being defended by a kind of keel running round and projecting beyond the shell. Both from its position, and its comparatively small size, this organ seems, at least in many species, to have been less important to the animal than is the case in the Nautilus; and it is probable that the change of position may have corresponded to some alteration in the arrangement of the viscera, or that, if the siphuncular tube entered the pericardium, as in the recent Cephalopoda inhabiting multilocular shells, it did so under other conditions than those which obtain in the living analogue.

Next to the Ammonite the *Belemnite* is the most interesting of the Lias Cephalopods, and remains of it have been found extremely perfect, both in the shales and limestones of Lyme Regis, and also at Whitby. These consist (1) of a solid calcareous portion, hollowed at one ex-

* In this statement of the case I have not alluded to the more frequent occurrence and close arrangement of the septa in the Ammonites, although there seems to be some difference also in this respect; and I have considered the complications of the septa without any regard to the view taken by M. Von Buch on the subject,—a view which, however, has been already alluded to.

tremity, and tapering at the other to a point,* (2) of a thin horny continuation of the shell, commencing at the base of the hollowed extremity, and enlarging rapidly as it extends beyond it, and (3) of a thin conical chambered portion, called the Alveolus, internal casts of the chambers of which are often found detached, as are also, although much more rarely, the walls of the chambers themselves, pierced on what appears to have been the dorsal margin, with apertures for a large siphuncle. The Alveolus was unquestionably placed within the thin horny continuation of the shell; and this latter was probably itself originally composed of horny matter, and was entirely contained within the body of the animal. The solid cone, filled with carbonate of lime, (which is crystallized in radiating fibres,) is that portion of the fossil most commonly found, and that to which more especially the name Belemnite was originally applied: it is often covered externally with vascular impressions, derived probably from the mantle of the animal, and, in some instances, is granulated like the horny coating of the calcareous shell of the common cuttle fish.

BELEMNITES OVALIS.

One of the most interesting facts in the history of the Belemnite is, that like some of the existing naked Cephalopods, the animal was provided with a contrivance for darkening the water with an inky fluid, and so, in the

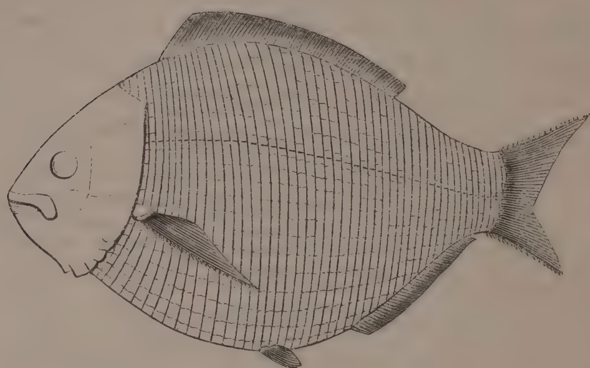
* This, at least, is the usual form; but it varies much, and, in some species, is of the shape of a short flattened cylinder, with a rounded end, while other species again exhibit still more curious anomalies.

obscurity which it created, escaping from its enemies. This so called ink in the recent cuttle fish is a black viscid fluid, about the consistence of printers' ink: it is suspended in the cells of a thin net-work, which pervades the interior of a bladder-shaped sac, and is ejected by what is called the *pen*,—a horny body not unlike a quill, constructed so as to force the ink from the sac with considerable violence. An arrangement precisely similar was provided for the Belemnite; and so similar is it, that the ink has actually been worked up as a pigment, and found to possess all the properties of that obtained from the recent Sepia. The ink-bag also has been recognised within the anterior horny sheath, once attached to the solid continuation of the shell; and, in the specimen figured, the whole apparatus occurs *in situ*, the Belemnite, with its anterior sheath continuous, the Alveolus or internal chambered portion in its place, and the ink-bag and pen adjacent to one another: no doubt, nearly in the position they occupied during the lifetime of the animal.

The Belemnite thus possessing the means of escape granted to the naked Cephalopods, in addition to the chambered shell and siphuncle of the Nautilus, Ammonite, and Orthoceratite, was doubtless exposed to greater dangers than any of these. Like other animals of its race, it was probably extremely voracious; and it appears to have flourished at a time when the seas swarmed with living creatures of almost every kind, amongst them being some of the largest, most powerful, and fiercest animals ever inhabiting the earth. Some of the Belemnites seem to have attained a considerable size; and they may have formed part of the prey of those large reptilian animals of which we shall speak in the next chapter.

CHAPTER XXIII.

FOSSILS OF THE LIAS. VERTEBRATA.



DAPEDIUS POLITUM. Ag.
(*Restored outline.*)

The fossil remains of vertebrated animals hitherto found in the Lias are confined to the two classes of Fish and Reptiles; but in these they offer a succession of highly interesting and remarkable animals, which are so perfectly preserved, and their analogies so completely made out, that the description of them forms the most instructive and most interesting chapter in the Palæontology of the Secondary formations.

Not less than sixty species of fish, all of them extinct, have been described by Professor Agassiz from the Lias of Lyme Regis only, and almost all these are referrible to the first two of his four orders, viz., the Ganoids and Placoids. In the former the *Lepidoid* and *Sauroid* families contain

the most interesting of the Lias and Oolitic species; while, in the latter, the *Hybodonts* and *Cestracionts*, the ancient prototypes of the shark family, are almost the only ones represented.

The two genera of fish most common in the Lias have received the names *Lepidotus* and *Dapedius;* they both belong to the same (the Lepidoid) family of Ganoid fish, and they both have bony skeletons; the body is covered with enamelled rhomboidal scales, and the mouth provided with one or more rows of small teeth, numerous and close together.

The *Lepidotus*, a genus continued throughout the Secondary period, but of which half the number of determined species are found in the Lias, was a fish of moderate dimensions, not often exceeding a foot or eighteen inches in length, and somewhat resembling the carp in external form. The head is broad, the body elongated or spindle-shaped, and the tail forked or rounded; the back and belly are slightly prominent, and the whole body is covered with large thick rhomboidal scales, of which the outer, or exposed part, is thickly coated with enamel. The scales advance further upon those rays which form the caudal fin, on the upper than on the lower lobe of the tail; but there is no approach in osteological character to the Heterocercal structure.

The whole of the head in this genus is coated with enamelled bony plates, the jaws are short and rounded, and the mouth small: the margin of the upper jaw is fringed with small teeth of an obtusely conical shape, and the inside of the mouth is provided with several ranges of flat, powerful, crushing teeth, covering the palate, and indicating, probably, the omnivorous habits of the fish. In some species, the food of the Lepidotus seems to have consisted

of half-decomposed organic matter, and, perhaps, also of the smaller marine animals living near shore, or in a shallow sea.

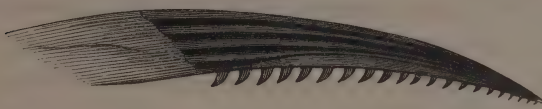
The *Dapedius*, a genus entirely confined to the Lias, is referred by M. Agassiz to a subdivision of the Lepidoid family, in which the body is flat and broad, and the tail regular. The species figured is among the most common of the Lias fossils, and is characteristic of the formation. Its remains are often found quite perfect.

The great peculiarity of the Dapedius consists in the form of the bones of the head, which are so remarkable that they can readily be identified, even when detached and in fragments. The jaws are short, the lower one broad and almost as high as it is long, and its fore-part is depressed towards the middle to receive the upper jaw. The other bones of the mouth, and the whole of the palate, are covered with many successive rows of teeth, which become smaller as they recede within the cavity of the mouth.

In the species already referred to, and which is figured above, the external enamelled surface of each of the bones of the head, is covered by granulations, which even extend to some of the scales near the head. The rest of the scales, however, appear perfectly smooth to the naked eye, although, when examined under a microscope, fine undulating striæ may be distinguished upon them.

The remaining fish of the Lias, those at least which are sufficiently remarkable to require distinct notice in this place, belong to the Placoid order, and chiefly to that family which is represented in modern seas by the shark tribe; but amongst the remains referred to these fish there are some of so curious a nature, that it will be necessary to allude to them rather as a special class of fossils, under the

name *Ichthyodorulites*, than as belonging to particular genera or species described in detail. They consist of the bony rays of the fins of certain cartilaginous fish, and



ICHTHYODORULITE.

an idea may be formed of their appearance by referring to the annexed figure, in which is represented a very small one found in the Lias. They occur in the beds of the Oolitic group, as well as in the Lias; but are most abundant in the latter formation.

The real use of these peculiar contrivances might long have remained involved in obscurity, were it not that an existing species of shark, (*Cestracion philippi*,) inhabiting the seas near the south coast of Australia, has been found to possess a similar weapon, armed, like the Ichthyodorulite, with tooth-like hooks or prickles on its concave side. In the Port Jackson shark (as this existing species is called) the bony spine serves as an attachment for the dorsal fin; and by its means the fin thus attached aids in effecting a singular rotatory motion of the body of the animal, when it is about to seize its prey. Neither the fin nor the bony spine by which it was supported are articulated to the vertebræ, but they are simply inserted into the flesh, sloping away towards the extremity of the inserted part, and terminating in an obtuse point. This singular method of attachment accounts for the fossil being invariably found apart from any remains of the animal; for, being itself solid and indestructible, and the rest of the skeleton soft and cartilaginous, it would readily be detached soon after

the process of decomposition had commenced. The most remarkable fact connected with these spines relates, however, rather to their internal structure than to their external appearance; for other fishes besides sharks have bony spines, and some are provided with a similar contrivance, which is used as a defence.

The internal structure of Ichthyodorulites has been recently explained by Prof. Agassiz, who states, in the course of his description of fossil fishes,* that, on careful examination under the microscope, they are not to be distinguished from teeth, and that they are, in fact, true teeth implanted in the external skin, instead of being buried in a jaw and placed in the mouth. In illustration of this, he observes, that in some cases they have a pulpy cavity occupying the centre of the spine, (or tooth?) surrounded by solid dentine (the bone of teeth), in which there are the usual tubes radiating towards the surface; and that in others there is a simple cavity surrounded by dentine, which is folded and twisted in various ways, and traversed by secondary medullary canals; but that often there is no principal cavity, and one can only observe isolated medullary canals, surrounded by their systems of calciferous tubes, and forming a fine net-work by the union of the extremities of these tubes with one another. There is, however, in every case only one substance (dentine), and the appearance of enamel sometimes seen on the external surface is only caused by a harder bed of dentine, in which the medullary canals are wanting.

With the exception of these singular rays or spines, there are usually no other remains of the extinct species to which they are referred than the teeth; and it has not been found possible to connect the one series with the other and

* Poissons Fossiles, vol. 3, p. 212.

identify any of the teeth with species determined by the examination of the Ichthyodorulites. Generic distinctions common to both have, however, been made out, and a genus, named *Hybodus*, includes the greater number of the fossil sharks. The Hybodus is described as having been provided with two dorsal fins, each of them having bony spines of comparatively large size, somewhat curved in shape, and broader towards the base than at the other extremity. The part of the spine originally inserted in the flesh was considerable, (often as much as a third of the whole length;) the rest is marked with deep furrows, and the concave side is provided with two rows of small hooks approaching each other towards the pointed extremity, and gradually uniting into a single row.

The teeth of this genus are common and easily recognised. They consist of a central cone, furrowed, and pointed, and flanked with a certain number of smaller cones, gradually diminishing in size, on each side of the middle one. The whole is covered with enamel, arranged in folds which are vertical with respect to the cones, and which are usually continued to the point, but more decidedly exhibited towards the base. The root of the tooth is large and bony.

It is not easy to conjecture what may have been the appearance of a fish, from the examination of its teeth and fins only. The Hybodus, however, was probably of large size, and from the form of its teeth there is sufficient evidence of its having been extremely voracious. It was, doubtless, fitted to pursue and destroy large fish; and, as such habits are inconsistent with a heavy shapeless form, must have been well-proportioned and adapted for rapid motion through the water.

The Reptilian remains of the Lias belong, for the most

part, to two genera of the order *Enaliosauria*, or marine Saurians, a group first fully developed in the strata of the Liassic system, and continuing throughout the Secondary period, but entirely lost before the commencement of the formation of tertiary strata: a group, therefore, only known by the remains of various species in a fossil state, but which, notwithstanding, abounds with the most interesting analogies, connecting it with several existing species, and uniting many remarkable peculiarities of structure.

It must not be assumed that all aquatic Saurians whose limbs are modified for swimming belong necessarily to this order of Enaliosaurians; certain modifications of the form of the skull and vertebræ, and an entire departure from the ordinary Crocodilian type in the method of articulation of the vertebræ, and also in the position of the breathing apertures, together with a peculiar form of the bones of the extremities, which in the extinct order were enveloped during life in a simple undivided tegumentary sheath,— these are the chief peculiarities; but they cannot be expected to include all the numerous details, upon a careful consideration of which the subdivision was grounded.

The two genera of Enaliosaurian reptiles whose remains occur in the Lias are called respectively Ichthyosaurus, and Plesiosaurus: the former exhibiting both in form and structure an approximation to the fishes, while the latter more nearly resembles the Crocodilians and land Saurians; but both of them present extraordinary and interesting deviations from the typical form of the class to which they are referred.*

* I have not thought it necessary to give engravings of these extinct Saurians, as the small dimensions to which they must have been confined would have rendered it impossible to exhibit the points of interesting detail in such a way as to be of any real advantage to the student. Most persons, also, have the means of examining for themselves the magnificent specimens in the collection at the Bri-

The Ichthyosaurus, or *Fish-Lizard*, must have resembled externally some of the huge predatory fish; but it was provided with a much larger head, a longer and more powerful tail, (expanded, however, vertically like the caudal fin of a fish,) and a naked skin without scales, and covered with smooth and fine wrinkles, not unlike those upon the back of the porpoise. Beneath this apparently simple exterior there were concealed peculiarities of conformation, which it will be necessary to explain in some little detail.

The form and structure of the head, and the important organs connected with it, first demand attention, as these differ in almost all respects from the structure of the same part in fishes, and much more nearly resemble the Crocodilian type.

The head in all species of Ichthyosaurus is of exceedingly large size, as compared with the entire length of the animal. The chief part of this length is owing to the unusual proportions of the jaws, and in some of the large individuals of which fragments are preserved, the gape or opening of the jaws must have exceeded seven feet: the jaws, however, are slender, and taper off gradually to the extremity. In the head of a predatory animal thus constructed, it was clearly important that the slender jaws should be as strong as possible consistent with lightness; and this was effected by a very beautiful mechanical contrivance, enabling them to resist and distribute the shock of a sudden and violent snap, such as they must have been constantly exposed to during the life-time of the animal. Instead of being formed of a solid piece of bone, they are made up of a number of parallel plates of unequal thick-

tish Museum, or in some one of the numerous collections distributed throughout England, and to be met with in almost all local museums.

ness and length, and of which the direction of the fibres in some is transverse to that in others: these plates are most numerous and strongest at the part where the greatest resisting power was required, but thinner and fewer towards the extremities where the service to be performed was not so considerable.

Along the whole length, on both sides of each of these jaws, a row of powerful teeth extended (see figure, p. 345), the teeth being somewhat obtusely conical, large, and deeply furrowed; not placed each one in a perfect socket, but separated from one another only by a slight ridge of bone, and fixed in a kind of trough cut in the jaw. As in the Crocodile, however, a constant succession is ensured during the life-time of the animal, a new tooth being always ready to replace the old one, and the number of teeth being very great.*

The large size of the eye (sometimes as much as eighteen inches in the diameter of the orbit,) is another matter worthy of remark in considering the head of the Ichthyosaurus. The eyes were placed far back behind the snout, and were partly defended by a circular series of thin bony plates, (not unlike the scales of an artichoke,) ranged round a central aperture once occupied by the pupil. This apparatus of bony plates moveable over one another is not known to exist in any fish, but is found in some of the larger birds of prey, and in a few lizards; its object in these animals seems to be to vary the sphere of distinct vision, and allow objects to be discerned clearly at great distances, without taking away the power of the distinct vision of near objects. The bony plates are also useful in maintaining the prominent position of the front of the eye.

* More than 180 have been found in the jaws of one individual.

In the Ichthyosaurus the similar contrivance above described must have given additional strength to the surface of the eye, protecting it from many injuries to which its large size would have exposed it; but it was no doubt principally useful in enabling the animal to adapt its powers of sight to both land and water. "The eye was thus an optical instrument of varied and prodigious power, capable of adapting itself to great changes of distance, and great alterations in the amount of light in which it could be used, giving to its possessor the power of discerning a far distant object as well as one near at hand, and of pursuing its prey in the darkness of night, or the dim obscurity of the depths of the ocean, as well as in the daytime or on land.*"

The Ichthyosaurus being a reptile, and therefore an air-breathing animal, it required to come occasionally to the surface like the whale; but in reptiles it is only a portion of the blood in the heart that requires to be aerated at each respiration, and these occasions are, therefore, far less frequent than in Mammalia. The nostrils, or breathing-holes, in the Ichthyosaur are placed near the top of the head; and thus almost the whole of the animal might continue below the surface during the process of respiration.

The body of all known species of Ichthyosaurus was attached to the head by the usual number of cervical vertebræ; but these (as in the whale) were so completely united into a mass of solid bone as to take away all appearance of neck. The rest of the vertebral column, however, consists of a large number of joints (about 120), each of which being constructed, as in the fish, with a double hollow, and the interspaces filled with fluid, every

* Buckland's Bridgewater Treatise, vol. i p. 173.

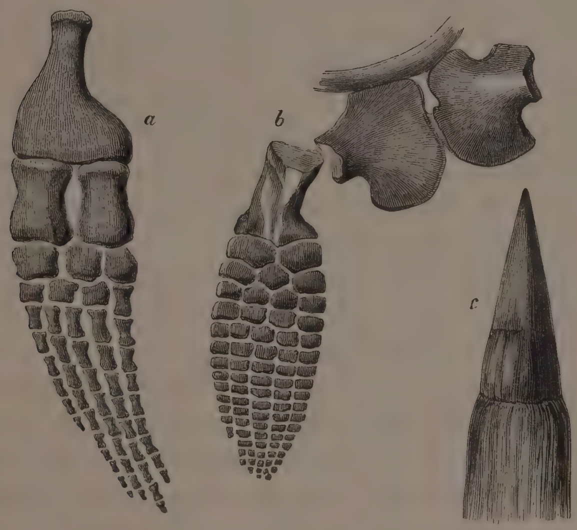
possible advantage was given to enable the animal to move readily and rapidly in the water; while the ribs attached to the vertebræ being numerous, slender, and continued along the whole length of the body to the pelvis, and those across the chest connected together by intermediate bones, the greatest amount of strength was in this way also communicated at the smallest expense of material.*

Connecting the bones of the anterior extremities with the vertebral column and the chest, there is another interesting mechanism observable in the Ichthyosaurus, and existing in no other animal, except the *Ornithorhynchus*, or Duck-billed Platypus of New Holland, and which, therefore, seems to indicate habits of the extinct reptile, analogous to those of the latter anomalous species still an inhabitant of the earth. The contrivance in question consists of an enlarged coracoid bone,† and a peculiar complication of the pectoral arch, in which this part of the skeleton of the Ichthyosaur differs entirely from that of the marine Mammalia,—the only animals in which, from the structure of the extremities, we can look for an analogy. Now as the Cetaceans were not intended to quit the ocean, and never require to do so, they are totally helpless on shore, and when, by any accident, they are stranded, they cannot regain their native element; but, on the other hand, the Ornithorhynchus (and doubtless in ancient times the Ichthyosaurus also), whose fore-paddles are directed outwards so as to act most advantageously

* This latter arrangement, also, is supposed to have enabled the animal to introduce into its body a large quantity of air, (the intermediate bones across the chest being in separate portions and moveable amongst each other,) so that it could have remained for a long time without coming to the surface.

† The *coracoids* are the bones by which the *furculum*, or merry-thought, of a bird is attached to the breast-bone.

against the water in swimming, is still so constructed that it can make use of these fore-paddles to react upon the body, by means of a strong apparatus of bone introduced between the two shoulder-joints, which are thus prevented from yielding inwards, and compressing the soft muscular masses.



a. LEFT FORE-PADDLE OF PLESIOSAURUS MACROPTERUS. OWEN.
b. LEFT FORE-PADDLE OF ICHTHYOSAURUS.
c. TOOTH OF ICHTHYOSAURUS COMMUNIS. CONYBEARE.

The extremities of the Ichthyosaurus are known to have been developed in the shape of paddles, not unlike those of the marine turtles; but in some respects they approached still more nearly in character to the fins of fish, the number of phalanges, or particles of bone, of which each one is made up being irregular, and sometimes amounting to as many as two hundred. The discovery of the impression of the soft parts of one of the hind fins

of the most common species of Ichthyosaur has recently exhibited, even more decidedly than had been anticipated, the analogy that obtains in the Saurian we are describing with certain tribes of voracious fish, as the outline of the extremity of the fin is clearly defined, and the whole of the posterior margin contains the impression of a series of rays, which extend obliquely downwards, bifurcating as they approach the edge of the fin, and the two branches slightly diverging. From the rarity of their preservation it is clear that these rays were not osseous, and they were, probably, either cartilaginous or of that albuminous horn-like tissue of which the marginal rays consist in the fins of sharks. The anterior part of the fin was terminated by a smooth, unbroken, well-defined line, and appears to have been merely a reduplication of the integument.* The bones of the paddle are usually dovetailed into one another at the sides, so as to prevent any independent movement, and at the same time constitute an uniformly resisting framework; and the anterior paddles are usually, but not always, larger than the posterior. The dimensions of the soft tegumentary part are such as to show that, in the particular specimen examined, the total length of the fin must have been half as much again as that of the bony portion of it; but this proportion cannot of course be depended on in other specimens of different age, or in other species of the same genus.

The vertebræ are continued in the skeleton of the Ichthyosaurus to a very considerable distance beyond the pelvis, indicating the existence of a powerful tail. In the marine mammalia, such as the whale tribe, there is also a tail; but it is not so long in proportion, and it

* Trans. of Geol. Soc. of London. 2d Ser. vol. vi. p.199.

works horizontally, enabling the animal to ascend or descend rapidly through the water, but not in any way helping to produce motion in any other direction. The only indication of this peculiarity in the tail of the whale that can be discovered in the skeleton, consists in a very slight flattening of the sides of the caudal vertebræ.

With regard to the tail of the Ichthyosaurus there had been till lately nothing whatever discovered in the skeleton, by which the Comparative Anatomist could form an idea of its nature, or how far it resembled that of other reptiles. At length, however, it was observed by Professor Owen, that in a large number of specimens, in which the vertebral column of this animal was perfectly well preserved, there was an abrupt bend or dislocation of these vertebræ at a certain point, (about the thirtieth vertebra reckoning from the extremity,) and that at this point a ridge, traceable along the dorsal and lumbar into the caudal vertebræ, finally disappeared. At this same point, also, where the dislocation takes place, a little disarrangement of the bones is observable, but the rest are continued undisturbed quite to the extremity, the direction only being changed.

Now there is no modification of the vertebræ where this bend takes place, indicating that the tail there possessed greater mobility than elsewhere; and it is scarcely possible to imagine that any accidental force operating on the dead carcase could produce such a fracture, in several specimens from different localities, and always at the precise point alluded to. The accident must therefore have been in some way or other connected with the structure of the living animal; and Professor Owen has happily suggested as a sufficient cause, that there was in the living animal a large caudal fin; and that this, either by its

mere weight, or by the attack of some predatory fish, might give rise in many cases to the dislocation of the vertebral column near the point of attachment of the fin. From the form of the vertebræ it appears that such a fin could not be horizontal as it is in the whale; nor indeed is there any necessity for its being so, for the broad paddles must have answered nearly the same purpose; but on the other hand, a powerful vertical fin would give to the Ichthyosaurus, whose habits were undoubtedly predatory, the ease and rapidity of motion so necessary to it, and would also readily produce those lateral movements of the head required by a short-necked aquatic animal. Such a fin, therefore, there is little doubt was possessed by the Ichthyosaurus.

I have now described at some length the principal peculiarities in the skeleton of this singular genus; but, before concluding my account, I must also say a few words on the nature of its food, its internal structure, and its skin,—points concerning which it may seem, perhaps, impossible that we should have any distinct knowledge, but of which, notwithstanding, the Comparative Anatomist has reason to speak with certainty.

The inferences that might be drawn from the formidable apparatus of teeth, the structure of the jaws, and the other evidences already given of the predatory habits of the Ichthyosaurus, have been fully borne out by the discovery of fragments and half-digested remains of fishes and reptiles, actually remaining to this day in the abdominal cavity in some specimens, the animal, overtaken by a sudden accident, having been destroyed before its last meal was entirely digested. But this is not all:—there occur also at Lyme Regis, and in other Lias localities, peculiar fossils called Coprolites, (*κόπρος*, *dung*,

λίθος, *a stone*,) which, on careful examination and comparison with similar masses found actually within the body of the Ichthyosaur, are known to be the fœcal remains of animals of that genus.

The Coprolites are often loaded with scales of fishes, and occasionally teeth, fragments of bone, &c., both of fishes and reptiles are contained in them, having evidently passed undigested through the stomach. Fossil remains of this kind are also so exceedingly abundant, that, in some parts of the Lias they form actual strata many miles in extent, presenting the strange appearance of a conglomerate, made up of the exuviæ of animals which inhabited the sea at the period of the formation of the bed.

Besides these rejected and totally indigestible portions of the food of the Ichthyosaurus, there have also been found within the cavity of the ribs in some specimens, large masses of half-digested matter. From the way in which these occur it has been thought extremely probable that the stomach of the animal formed a pouch of prodigious size, extending through nearly the entire cavity of the body; and that it was therefore of a capacity well-proportioned to the powerful jaws and teeth, which were exerted to supply its wants. But with so large a stomach there could be very little room for an elongated intestinal canal; and the shape of the Coprolites, which are spirally twisted, indicates also that this part of the animal economy consisted of a flattened tube, reduced to the smallest possible dimensions by being wound round in a spiral, like a corkscrew.

It has been already mentioned, that careful observation has indicated to the Palæontologist the nature of the integuments upon the paddle, or fin; but the skin of other parts has also been made out, and we are thus able to state, that in this respect the Ichthyosaurus departed

from the Crocodilian type, and resembled the Cetaceans, having a fine wrinkled epidermis, without scales, on the lower part of the body; it also appears, from the regularity of certain markings on the fin, that there was a division of that organ into a number of shield-like compartments, analogous to those on the paddle of the turtle, and not unlike the webbed foot of the crocodile; so that in this way even the integument exhibits some of the characters of those of existing reptiles.

Recapitulating now the points to which attention has been chiefly directed in the account of this interesting animal, we find that the Ichthyosaurus was an air-breathing marine reptile, attaining sometimes a length of upwards of thirty feet, whose general outline resembled, perhaps, the recent porpoise, but whose head, jaws, and teeth were like those of a crocodile. We find too that, associated with this crocodilian head and eagle eye, there existed the vertebræ and the caudal fin of a fish, the sternum of an Ornithorhynchus, and the paddles of a turtle attached like the fins of a whale. The capabilities of locomotion, and the means of offence and defence, seem to have been at least as great as in any known animal, and the contents of the stomach fully bear out the character of the teeth. Not less than ten species are known, and they range through the whole of the Secondary strata, even to the lower beds of the Cretaceous system; but their remains are chiefly abundant in the Lias, and there can be no doubt, that during the formation of that rock, they performed a most important part among the inhabitants of the globe, and they are among the largest, the most powerful, and the most voracious species of whose existence man is cognizant.

Associated with the Ichthyosaurus in the Lias, there are

found the remains of another genus of marine Saurians, of which the external shape is much more strikingly different from that of any other animal than is the case with the fish-lizard, but which, approximating more nearly to the Saurian type in many points of structure, has received the name Plesiosaurus (*πλησίον, near, σαῦρος, a reptile*). This animal may be described as exhibiting the head of a lizard, attached to a neck whose length was three or, in some species, even more than four times that of the head. The body appended to this head and neck was comparatively small and fish-like, the extremities were large paddles, and the tail like that of a crocodile. Let us consider a little in detail the real extent of the singular and anomalous points of structure thus united in one animal.

The head of the Plesiosaurus is of very small dimensions compared with the length of the body, and it forms a kind of link between the Lacertian and the Crocodilian types: resembling the former both in the elongated form of the bones and the wide interspaces between them, but approaching the latter in the proportions of the jaw, in the rugged exterior surface of the bones, and above all, in having distinct sockets provided for the teeth. The size and position of the external nostrils or breathing holes (which are double, and placed a little in front of the orbits near the highest part of the head,) form, however, a striking exception to the arrangement of these parts in the crocodile, and exhibit interesting analogies with the Cetacean tribe.

The most remarkable peculiarity of structure in the Plesiosaur consists in the unusually long and flexible neck with which the animal was provided, and the great number of the vertebræ (amounting to upwards of thirty) of which it was made up. This large number of joints must have

rendered the neck extremely flexible, and moveable with perfect facility, and probably with great rapidity and precision. It appears, from the remains of small false ribs, which have been attached to the cervical vertebræ, that the neck swelled gradually, but considerably, from the head towards the body; and there can be no doubt that the animal was enabled to obtain its prey, and defend itself against its enemies, by means of the powerful and rapid motion it would be enabled to communicate to its wedge-shaped head.

The structure of the vertebræ is not doubly concave, as in the Ichthyosaurus and in fishes; nor is it concavo-convex, as in crocodiles: the surfaces opposed to each other are nearly flat, and in this way much better able than those of the Ichthyosaurus to give strength to the extremities, and enable them to support the weight of the body. And this structure of the back-bone was doubtless required by the habits of the animal, whose large and powerful paddles needed some such solid column against which to work. The whole arrangement of the vertebræ and their processes resembles considerably that of the land Saurians, and the tail, which was short and powerful, was intended apparently rather to serve as a rudder than as an organ of locomotion.

In the Plesiosaurus the ribs are composed of several distinct and separate parts, each pair of ribs, proceeding from the opposite sides of a vertebra, being united by a complicated contrivance of three bones folded one over another, and forming, together with the ribs, a complete, elastic and powerful belt, permitting great expansion of the abdominal cavity during the inflation of the lungs. This apparatus also is connected with a powerful sternal apparatus, locking the anterior extremities of the animal

to the solid framework of the vertebral column. A somewhat similar contrivance in the ribs has been before alluded to in describing this part of the Ichthyosaurus; but it is far more completely and perfectly developed in the genus we are now considering.

The paddles of the Plesiosaur departed much less widely from the Cetacean type than those of the allied genera of extinct marine Saurians, and the number of the digits is limited to five, although the phalanges are more numerous than in existing Cetaceans or reptiles. The whole of the phalanges of each extremity were, no doubt, enveloped in a common integument, and the resulting paddle appears to have been long and slender, to have had an elegant and tapering form, and to have possessed greater flexibility than in the Cetaceans. In most of the species the paddles are very large in proportion to the size of the body, and are evidently so constructed as to be most efficient swimming instruments; so that, in spite of its long and apparently unwieldy neck, the animal could doubtless move through the water with very great rapidity, either in pursuit of its prey, or to escape from its enemies. In that species* in which the paddles are the largest and most powerful the head is comparatively small, and the neck and tail both large; although, in another species (*P. macrocephalus*) where the head is large and powerful, and the neck comparatively short, the paddles are also large, and even somewhat longer in proportion than in the common species. About eighteen species are known at present, of which, however, six occur in strata of more recent date than the Lias.

* *P. macropterus.* A magnificent specimen of this (from Whitby) is in the Woodwardian Museum of the University of Cambridge. The left fore-paddle will be seen figured in page 345.

The Plesiosaurus was, like the Ichthyosaurus, a voracious and carnivorous animal, feeding, no doubt, indiscriminately on every kind of animal food that came within its reach, and even on the young of its own species. It attained a large size, a perfect specimen existing of the length of seventeen feet, and fragments of much larger individuals having been found. Although its proper habitat was the sea, and its strange proportions seem to render it unfit to move about on land, it was at least as well adapted to do so by the structure of its extremities, as the seal or any other of the Linnæan Amphibia.

It has been suggested that, in order to obtain its prey, this animal might have hidden itself among reeds, and darted like a serpent upon any unhappy victim passing within reach; but such concealment will appear to have been quite unnecessary when its great powers of swimming by means of its enormous paddles are taken into consideration.

In spite of the attacks of the Ichthyosaurus, the Plesiosaurus must have been exceedingly abundant during the Liassic period, but that it was no match for its powerful enemy, and not unfrequently fell a prey, is evident from the undigested fragments of its bones being found among the Coprolites already described. It is not, however, probable, that any other of the inhabitants of the sea could have interfered with its rapacity.

Besides these two remarkable genera of Saurians the remains of another, referred to the order Pterosauria, are also found occasionally in the Lias; but, as they are more common in the formations of the Oolitic system, an account of them will be deferred to a future chapter. The *Teleosaurus*, a crocodilian reptile, might also come under consideration here as a Lias fossil, but it will be more

convenient to speak of that also among the organic remains of the Oolites. Enough has been said to show how great an interest attaches to the Lias, a formation containing within it numerous and varied instances of the most strange peculiarities of structure, introduced to the Zoologist by the study of Palæontology.

I have subjoined here, and at the end of one or two subsequent chapters, some specimens of vegetation which may serve to give an idea of the more remarkable peculiarities exhibited by the flora of Southern latitudes. Some of these are from New Zealand, and others from the various islands in the Southern Seas; and they illustrate the probable condition of the vegetation of the northern hemisphere during the deposit of the Carboniferous and Secondary rocks. The drawings for these cuts were mostly taken from the beautiful plates in Dr. Urville's Account of the Voyage of the Astrolabe.

CHAPTER XXIV.

THE ROCKS OF THE OOLITIC SYSTEM IN ENGLAND.

The strata which in this chapter will be described under the general denomination "*Oolites*,"* comprise an extensive group of limestones and clays, with a few subordinate arenaceous beds, the whole resting on the Lias, and overlaid either by the Wealden formation, or in its absence by the lower sands of the Cretaceous system. This formation, represented on the Continent of Europe by what is there called the "*Terrain Jurassique*," or "*Jura-kalk Formation*," is not so remarkable for its thickness, or extent, as for the great number and variety and the economical importance of the beds of which it is made up, and although it does not form part of the plan of this work to describe in minute detail either formations or fossils, it will be necessary to speak of several even of the subdivisions of the Oolitic series.

The following is a tabular view of the different strata of which the English Oolitic system is composed, and with the assistance of the various sections in this and the following chapter, some idea of the relative importance of

* This name (Oolite) is derived from the peculiar appearance of many of the limestones of the series, which seem as if made up of an infinite multitude of small egg-shaped particles, (ὠὸν, an *egg*, λίθος, a *stone*.) The oolitic character, however, is not confined to any particular geological formation, but is found in some of the carboniferous limestones, and also in Tertiary beds.

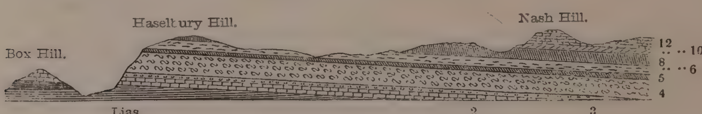
most of the groups may be obtained. The sequence, however, is not exactly the same in different parts of England, and there is, perhaps, no locality where the whole series occurs.

OOLITIC SERIES.*	UPPER OOLITES.	14. PORTLAND STONE.
		13. *Portland sand.*
		12. KIMMERIDGE CLAY.
	MIDDLE OOLITES.	11. *Upper calcareous grit.*
		10. CORAL RAG.
		9. *Lower calcareous grit.*
		8. OXFORD CLAY.
		7. *Kelloway's Rock.*
	LOWER OOLITES.	6. *Cornbrash.*
		5. *Forest marble*, replaced in the North of England by sandstones and shales, which are sometimes carbonaceous.
		4. GREAT OOLITE, a coarse shelly limestone alternating with fine building-stone: sometimes replaced by an argillaceous bed well known as the *Bradford clay* (4′).
		3. A number of strata consisting in the North of England of *Carbonaceous gritstones* and *shales;* in Oxfordshire represented by the *Stonesfield slate;* and in the South and West of England by rocks containing *Fuller's earth.*
		2. INFERIOR OOLITE.
		1. *Calcareo-siliceous sand* alternating with and passing into the upper Lias sandstone.

The general appearance of the Oolites in England may be described as consisting of three ridges, running north-east and south-east (or rather N. N. E. and S. S. W.) with three extensive and rich plains intervening. The ridges, in this case, represent the escarpment of the hard limestone beds of the Lower, Middle, and Upper Oolites respectively, and the plains the softer and less coherent clays and shales alternating with them. The Lower

* The numbers given to the different strata are referred to in the various diagrams in this chapter.

Oolites lap over the great plains of the Lias on the west, and on the east the green sand of the Cretaceous system usually forms a low escarpment on the Kimmeridge clay, or caps the uppermost beds of the oolitic series whatever they may be. In the centre of England, the Portland beds are usually absent; in the west, and in the vicinity of Bath, the whole sequence is nearly perfect; in the south, the Great Oolite, (which forms an escarpment near Bath,) is absent, and replaced by the Forest marble, while the Portland rock occupies an important place in the sequence; and lastly, in the north, it is chiefly the central portion of the system that is developed, and the Coral rag there attains its maximum of thickness and importance.



SECTION ACROSS SOMERSETSHIRE AND WILTSHIRE

I. The Lower Oolites.

The proper base of the Oolitic system in the west and south of England seems to consist of a slightly micaceous yellow sand, often friable and incoherent, and slightly calcareous. To this succeed a number of beds of hard shelly limestone, surmounted by a thickness of about forty or fifty feet of freestone, the *Inferior Oolite* (2) forming the first true Oolitic limestone met with in the rocks of the Secondary Period.* In the North of England these calcareous

* A bed of Oolitic limestone occurs, indeed, in the Mountain limestone of Derbyshire, but the particles of carbonate of lime in the Muschelkalk and the Lias appear to be totally devoid of any tendency to arrange themselves into this singular structure.

beds are not present, and we find them replaced by sandstones and ironstone.

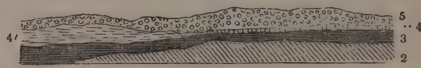
The Inferior Oolite is separated from the Great Oolite (or principal bed of freestone in the lower part of the Oolitic system) by a series of marly beds, containing amongst them a particular kind of clay used in the manufacture of cloth, and called "*Fuller's earth*," and also a thin bed of calcareous flag-stone, known as the "*Stonesfield slate*." The former stratum, the Fuller's earth, is chiefly found at Odd Down, and on the side of Midford Hill near Bath;* but it forms only a small and unimportant member (geologically speaking) of the argillaceous deposit beneath the Great Oolite. The Stonesfield slate occurs in two beds, separated by a loose calcareous sandstone, and is chiefly worked for flagstones and tiles, in quarries dug near the village of Stonesfield in Oxfordshire. It has long been celebrated for the singular nature of the organic remains found embedded in the fissile limestones which compose it, and beds somewhat similar, and also fossiliferous, occur also at Colley Weston, a village near Stamford in Northamptonshire. These latter, however, probably belong to a higher part of the Oolitic series.

The Great Oolite (4) consists of a variable series of coarse shelly limestones (locally called "rag"), alternating with beds of fine soft freestone devoid of fossils, and admirably adapted for building purposes. The lowermost strata (at the junction with the Fuller's earth) are fine-grained, scarcely Oolitic, and almost crystalline in their structure; but the lower *rags* overlying this bed are composed of shelly limestones and coarse freestone, and upon these rests the well known "Bath Oolite." This is

* Transactions of Geol. Soc. of London, vol. iii. p. 250.

succeeded by a number of alternations of harder and coarser limestones, of a yellowish-white colour and highly fossiliferous, some of which also supply good building material.

The position of the *Bradford clay* with respect to the Great Oolite will be best understood by referring to the annexed diagram. The clay appears to be of somewhat



POSITION OF THE BRADFORD CLAY AND GREAT OOLITE.

newer origin than the limestone, but was no doubt partly contemporaneous, and it is occasionally the only stratum intervening between the Fuller's earth and Forest marble, even when there is no appearance of any interval having elapsed between the two deposits. It consists, usually, of a pale greyish clay, containing a small proportion of calcareous matter, and inclosing thin slabs of tough brownish limestone. Its thickness appears never to exceed sixty feet; it is often entirely absent, and at other times is so obscurely interstratified with the underlying Fuller's earth, or the overlying Forest marble, as to be scarcely recognizable.

The Bradford clay is particularly remarkable amongst the Oolites for the abundance in it of a peculiar fossil, the *Apiocrinite*, whose remains are usually found in groups, the stems of the Encrinites being attached to the thin bands of limestone interstratified with the clays.

In Yorkshire this part of the series consists of nodules of ironstone over-lying hard blue and fine-grained limestone, the whole series being non-fossiliferous, with the exception of fragments of bone and the shells of marine mol-

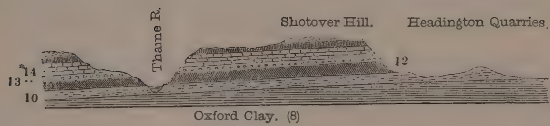
lusca, around which the iron-stone nodules have formed. The hard limestones are extremely durable, and have been found well adapted for various economical purposes: more especially for works exposed to the beating of the waves, where smoothness of surface is not required.

The Bradford clay is succeeded by a thin and often calcareous gritstone, covered up first by a sandy clay, and then by a thickness of about twenty-five feet of workable limestone. This latter is called *Forest marble*, and it consists of carbonate of lime, sometimes crystalline, and sometimes marly. Organic remains occur in it, and occasionally in such great abundance as to make up the whole substance of the stone.

The last of the long series of the Lower Oolites is called *Cornbrash*. It consists of a variable thickness of clays and sandstones, which ultimately pass into a thin rubbly stone, tough and occasionally crystalline, capping the escarpment of the Lower Oolites, but frequently absent, or appearing only as an imperfect outlier. Its name is probably derived from the excellence of the corn land, which results from the decomposition of the limestones, and their mixture with the sandstones and clay.

Of this lower portion of the Oolitic system the bed called the Great Oolite is the most important, both in thickness and practical utility. It is also the most interesting, for it contains a series of fossil shells, (chiefly found near Minchinhampton,) perhaps the most extensive that has yet been determined from any single bed in the Secondary period. The Inferior Oolite, at Dundry, Bridport, and Leckhampton, also exhibits a rich and extensive series of fossil shells of extreme beauty, and in the most perfect preservation; but these, as well as the former, are for the most part undescribed.

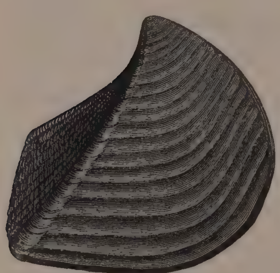
II. The Middle Oolites.



SECTION ACROSS THE MIDDLE AND UPPER OOLITES.

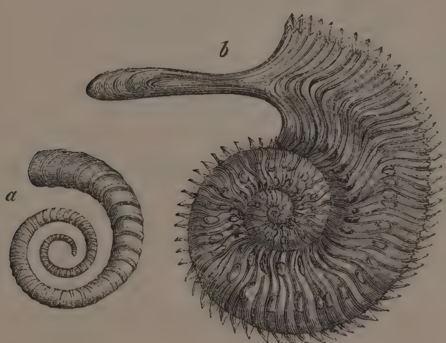
The central portion of the Oolitic system is not by any means so complicated, nor are the different beds of which it is made up so numerous or varied, as is the case with the lower portion just described. It consists, for the most part, of a thick bed of clay, called the Oxford clay (8), widely expanded throughout England and met with also in the same form on the Continent, together with a series of overlying limestones, chiefly remarkable for the abundant remains of corals found in them.

Although the Oxford clay in many places rests immediately on the Cornbrash, and thus forms the basis of the Middle Oolitic system, this is not always the case, and there is often an intervening stratum composed of calcareous sandstone abounding in organic remains, and sometimes entirely made up of them. This bed is called the Kellóway rock, or Kelloway's rock, and its thickness varies from three to five feet. The fossil represented in the annexed engraving is common in the Oxford clay, but is also found in several of the underlying beds as far as the lowest Oolitic strata.



TRIGONIA COSTATA. Park.

The Oxford clay—a most important member of the Oolitic series—attains a thickness of not less than five hundred feet, and is spread over a great part of England, more especially occupying the fen districts in the counties of Cambridge and Lincoln, which appear to be partly caused by the union of this bed with the Kimmeridge clay, and the consequently wide expanse of flat and undrained country. The Oxford clay is also well seen at Weymouth, and it covers an important part of the East Riding of Yorkshire. The stratification throughout is nearly horizontal and undisturbed, being conformable with that of the formations immediately above and below it.



a. CRIOCERATITES. U.S.
b. AMMONITES ELIZABETHÆ. PRATT.

The appearance of the Oxford clay is that of a stiff pale blue argillaceous bed, containing a large proportion of calcareous matter, and a more or less abundant mixture of iron pyrites. Numerous organic remains are found in it, which are sometimes preserved in the clay itself, but more frequently form a nucleus, about which iron pyrites have aggregated. Those preserved in the clay have commonly been found in a very rotten condition; but lately,

a portion of the bed being cut through in the excavations for the Great Western Railway, a considerable number of most beautiful and interesting fossils were discovered, chiefly the remains of Cephalopoda, exhibiting the perfect structure of the most delicate portions of shell, and even the remains of the softer parts of the animal.*

The upper beds of the Middle Oolitic series are partly calcareous and partly sandy, the former consisting chiefly of a very interesting group of corals, and being known in Geology under the name of CORAL RAG (10), and the latter —the sandy beds, (or *calcareous grits*)—often more or less intermixed with calcareous matter, and having thin laminæ of clay sometimes passing into irregular bands of hard and tough marly rock. This calcareous matter seems entirely due to the presence of crushed and decomposed organic remains.

It is chiefly in Wiltshire, near the towns of Calne and Steeple Ashton, and in the surrounding neighbourhood, that the corals of the Coral Rag are found in greatest abundance and perfection; and this part of our island at the time of the deposit, has clearly existed in the condition of a coral island in an open sea. The thickness of the bed is about forty feet; large portions of it are frequently made up of the remains of a single species, and an earthy calcareous freestone, sometimes used as a building-stone, and full of fragments of shells, rests immediately upon it, and is surmounted by a fine-grained ferruginous sandstone,

* The accompanying engraving represents one of these specimens in which the shell of an Ammonite (*A.* Elizabethæ) has been so well preserved as to exhibit the perfect aperture. Mr. Pearce has suggested that this terminal lip or mouth has a different shape in the young shell of almost every species, but assumes in the old a straight outline. He is further of opinion that, at different periods of the formation of the shell, the lateral processes were absorbed and reproduced, and that, therefore, they are found in various stages of growth, but are invariably wanting in the mature shell.—See Geol. Proc. vol. iii. p. 594.

slightly Oolitic in structure, and containing a few fossils, marking the close of the Middle Oolitic period.

CORALS FROM THE OOLITES.

a. Caryophyllia annularis. FLEM.
b. Scyphia articulata.
c. Myrmecium globatum.

In the north of England the contemporaneous bed is a calcareous deposit, also containing corals, but, (as at Malton, in Yorkshire,) including also a considerable proportion of the fossil remains of shells, both bivalves and univalves. It never, however, loses its coralline character, and this bed may, perhaps, represent an imperfect coral reef, extending from the south-west of England to what is now the right bank of the Humber.

III. THE UPPER OOLITES.

The upper beds of the Oolitic series, as well as the overlying Wealden deposits, are almost entirely confined in their development to the south of England, only that stratum of clay which usually forms the base of the group being exhibited in Yorkshire, in the vale of Pickering.

This great argillaceous deposit, the KIMMERIDGE CLAY (12), is of a blue, slaty, or greyish yellow colour; it frequently contains a considerable quantity of selenite or crystallized sulphate of lime; it usually effervesces with acids,

and exhibits in tolerable abundance both vegetable and animal impressions, although its fossils are rarely in such good condition as to be preservable in a museum. It is a bed of great thickness, horizontal, or nearly so, in its stratification, extremely persistent in its peculiar mineral and fossil characters, but not very extensively developed either in England or on the Continent. The name Kimmeridge Clay has been applied to it because it is well exhibited at Kimmeridge Bay, and near the village bearing the same name, in the isle of Purbeck.

SECTION. ISLE OF PURBECK.

At this spot also there are found, alternating with the clay, certain beds of highly bituminous shale, occasionally used for fuel, and locally known as the Kimmeridge Coal.* It is one of many beds of lignite found in the Oolites, but is perhaps the most remarkable of all.

It has been already mentioned that the existence of a calcareous rock overlying the Kimmeridge clay is not by any means universal. In the south of England, however, and more especially in the Isle of Portland, there is a very interesting and well defined group of limestones, well known under the name of "Portland stone," and valuable

* This so called coal is of a dark brown colour, and without lustre: it effervesces slightly with acids, contains no iron pyrites, and burns readily with a yellowish, rather smoky, and heavy flame. It is associated with slaty clays, abounding in pyritous matter, and from which formerly alum was made. Conyb. and Phil. pp. 177—8.

for building purposes, which rests upon the clayey beds of the upper Oolitic series, completing the sequence and connecting the Oolites with the fresh-water rocks of the Weald. It will be seen presently that this passage takes place under circumstances of unusual interest.

The group of strata containing the Portland stone, and exhibited in Portland Island, includes several layers of coarse earthy limestone, which rest on a bed of siliceous sand, mixed with green particles. This is called the Portland sand, and sometimes attains a thickness of as much as eighty feet in the west of the island, and forms a complete passage from the upper part of the Kimmeridge clay into the overlying series.

Above the coarse limestones of the lower part, which usually consist of alternate hard and soft layers to a thickness of fifty or sixty feet, there are three beds of serviceable stone, interstratified with clayey or siliceous bands: fossils occur in all these strata, but they are rare in those beds of the stone which are worked to advantage for economical purposes.

In the upper part of the Portland series, and forming, as it were, a finish to the whole Oolitic group, there occurs a very interesting bed, about a foot in thickness, of a dark brown substance, containing much earthy lignite.* This bed, called by the workmen "the Dirt-bed," seems to be made up of black loam, which at some far distant period nourished the roots of trees, fragments of whose stems are now found fossilized around it. Wherever the dirt-bed is laid open to extract the subjacent building-stone, these remains of trees occur, and they are placed at such distances from one another as trees growing in a modern

* Webster. Trans. Geol. Soc., 2nd Ser. vol. ii. p. 41.

forest. On examination there may be found an assemblage of silicified stumps, or stools of large trees, standing from one to three feet from the mould; most of them are erect, but some slightly inclined, and *the roots of these trees remain attached to the earth in which they grew.* The structure of coniferous wood has been recognised in some of these petrified trees, and similar wood is found in precisely the same situation with respect to the Portland formation on the coast of France, in the Bas Boulonnois, and also at the junction of the Oolites and the Weald in Buckinghamshire, and in the Vale of Wardour. It results from the circumstances of this deposit that the surface of the Portland stone, at the termination of the Oolitic period, was for some time dry land, and covered with a forest; and we have a kind of measure even of the duration of this period in the thickness of the dirt-bed, which has accumulated more than a foot of black earth, loaded with the wreck of its former vegetation. "The regular and uniform preservation also of this thin bed, over a distance of so many miles, shows that the change from dry land to the state of a fresh-water lake or estuary, (which the nature of the overlying rock proves to have succeeded the period of dry land,) was not accompanied by any violent denudation, or rush of water, since the loose earth, together with the trees which lay prostrate on its surface, must inevitably have been swept away had any such violent catastrophe then taken place."*

Having now concluded the account of the various subdivisions of the Oolitic group as they are met with in England, it is necessary, before proceeding to the con-

* Buckland and De la Beche, Trans. Geol. Soc. 2nd Ser. vol. iv. p. 16.

temporaneous strata on the Continent, that I should briefly notice several small but interesting formations representing, in North Britain, that extensive and important group of limestones and clays, which occupies so prominent a place in the Geology of the middle and south of England.

North of Yorkshire the Oolites are not to be found in the British isles as a regular formation, occupying its proper place in the geological sequence; but in two or three valleys on the south-east coast of Sutherland, on the eastern coast of Ross, and in some of the western islands of Scotland, there are not wanting proofs, that the same causes which produced the Oolitic series in the south were in action, and only required favourable circumstances to develope them. Of all these localities BRORA, a valley and loch remarkable for containing a coal deposit, which has been worked from time to time since the close of the sixteenth century, is, beyond all doubt, the most interesting, and is well worthy of notice.*

The district of Brora is about eight miles in length, and two and a half in greatest breadth. The carboniferous beds consist of three or four feet of fine cubical coal, (which burns well to a white ash,) resting upon bituminous and other shales, and alternating with shale and sandstone, and even, occasionally, with ironstone and limestone. The shales and sandstones frequently contain vegetable impressions, and occasionally shells, all of which offer satisfactory proof of the date of the deposit, proving it to belong to the Oolitic period, and to be of the age of the lower subdivision of the group. The usual type of structure, however,—the egg-shaped particles of which the limestones are made up,—

* See an admirable paper by Mr. Murchison on this subject in the Transactions of the Geological Society of London, 2nd Series, vol. ii. p. 293.

is completely lost, and indeed limestone in any form is extremely rare. The strata are identified by Mr. Murchison with those of the eastern moorlands of Yorkshire.

On the north-east coast of Scotland, both north and south of Brora, traces of the Oolitic strata are visible in low cliffs, exposed at ebb tides to a distance of 40 miles from north to south; and on the north-west coast different members of the same group extend through a space of 120 miles, frequently swelling into cliffs of great height. They are, however, much disturbed by igneous rocks, and the mutual relations of the beds are often equivocal, although the fossil remains of the whole suite are clearly referrible to various Oolitic formations.

CHAPTER XXV.

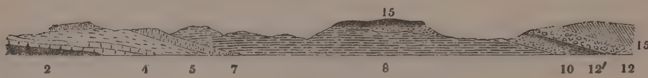
THE FOREIGN ROCKS OF THE OOLITIC PERIOD.

It might naturally be expected that so extensive a series of fossiliferous deposits as the Oolitic formations of England should not be unrepresented on the continent of Europe, and we do, in fact, find, not only a contemporaneous group of some geological importance, but also subdivisions, which, if not exactly parallel with our own, are yet sufficiently so to be compared and frequently identified with them by the evidence of fossils.

The principal localities under the head of which the Oolites of the continent of Europe may be most conveniently treated are, I. The department of the Calvados, and the adjacent district in the north of France. II. The Jura and its vicinity. III. Franconia and Northern Germany, more especially that part of the district in the north of Bavaria. IV. The extensive and disturbed Alpine district of this period; and, V. The representatives of the Oolitic series in the east of Europe, in Poland and Russia.

I. In the department of the Calvados, and generally in those parts of France adjacent to our own coasts, there is considerable resemblance even in the subdivisions of the contemporaneous formation, and the inferior Oolite is overlaid by the Great or Caen Oolite, and that again by several unimportant beds, not unlike those of the south of England, the whole being crowned, first by the Oxford clay, with its

characteristic fossils, and then by a rock representing the coral-rag, which has been thought by some French Geologists to pass into the Portland stone.



IDEAL SECTION ACROSS THE DEPARTMENT OF THE CALVADOS *

Of all these beds it is the Caen limestone, the supposed representative of the great Oolite, which best deserves the careful attention of British Geologists, not only for its economical importance, but also from its extreme richness in fossil remains, which are not confined to shells and corals, but include a considerable number of large Crocodilian reptiles.

The inferior limit of the Oolitic system in this part of France is somewhat obscure, the upper marly beds of the Lias passing insensibly into ferruginous Oolitic strata, the lowest of which is a calcareous grit of a yellowish or greyish colour, remarkable not only for its ferruginous character but also for the great abundance of its fossil shells. It

* The above section is reduced from one published by M. de Caumont to accompany his admirable memoir " Sur la Topographie Géognostique du département de Calvados," published in the Transactions of the Linnæan Society of Normandy; An. 1828, p. 59.

I have given below a double series of references, the numbers corresponding with those made use of in the former chapter.

15. Chalk and green sand.
12. Argile d'Honfleurs. (Kimmeridge clay.)
12′. Calcaire de Blangy.
10. Coral rag.
8. Argile de Dives. (Oxford clay.)
7. Kelloway's rock.
5. Calcaire à polypiers. (Forest marble.)
4. Calcaire de Caen. (Great Oolite.)
2. Oolite inferieure. (Inferior Oolite.)

is rarely more than three or four feet in thickness, and is overlaid by a white limestone, like that of Caen, divided into bands of various thickness ; and, although occasionally surmounted by a clayey bed, it more frequently passes at once into the great Oolite. This latter forms the extensive plains of Normandy : it lies nearly horizontal, and is chiefly exhibited in section on the banks of rivers, from which it is worked in numerous horizontal galleries. Associated with the limestone there is found a certain proportion of silex, chiefly in the form of black or yellowish flints, which are occasionally stratified, as in chalk, but sometimes disseminated through the mass: in the upper part of the group fossils are extremely abundant, and a very considerable number of interesting organic remains of fishes and reptiles is also found in the lower beds, which probably correspond with our Stonesfield slate. The building stone is of admirable quality, soft in the quarry, of a delicate uniform cream colour, and extreme fineness of texture. It hardens by exposure, though not till after some years, and has been very much used for many centuries, not only for the churches and public buildings of Normandy and the north of France, but also in other countries to which it is still exported in large quantities.

Immediately overlying the beds of Caen limestone is a fossiliferous stratum, locally called "Calcaire à Polypiers," from the number of coralline remains found in it. It is varied in its mineral character, sometimes appearing as a fissile limestone, but more frequently as a fragmentary rock very imperfectly cemented by a calcareous paste, and Oolitic grains of oxide of iron are found in the upper part, the grains being sometimes large enough to give the character of Pisolite to the mass.

A clay called "l'Argile de Dives," and representing

the Oxford clay in geological position, as well as mineral character, forms, with a band of limestone resting upon it, the middle group of the Normandy Oolites, and may be seen along the coast for a considerable distance. This clay is of a bluish-black colour, and the lower portion of it connects itself with the underlying formations by a yellowish, or blue marly calcareous sandstone, supposed to represent the *Kelloway Rock;* and this latter bed contains a sufficient proportion of calcareous matter to be occasionally burnt for lime. The clay, also, becomes hard in some localities, and has a conchoidal fracture, probably owing to the presence of calcareous matter.

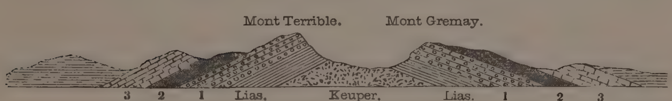
The overlying rock of the Oolitic series in this part of France is the "Calcaire de Blangy," and was at one time supposed by Sir H. de la Beche to represent the Portland stone:* but, according to M. de Caumont in the memoir already cited, it most probably replaces the Kimmeridge clay, and it rests immediately on a bed supposed to be contemporaneous with the coral rag. This limestone of Blangy is chiefly interesting as containing compact bands of exceedingly fine texture, sometimes capable of being used for lithographic purposes. At Honfleur there is a clay of considerable thickness, the true representative of our Kimmeridge clay, and containing many of the same fossils; but its most characteristic fossil is a small shell nearly allied to the oyster (*Gryphæa virgula*), also common in the neighbourhood of Ely. This bed, representing the Kimmeridge clay, is of a blue or bluish-grey colour alternating with blue marly bands in the lower part, and it is based in some localities upon a fine grained sandstone. Its total thickness is about a hundred feet, and in it, as in

* Geol. Trans. 2d Ser. vol. i. p. 77. See also Mem. de la Soc. Linnéenne de Normandie. Année 1828, p. 174.

the Calcaire de Blangy, there occur flattened nodules of compact lithographic limestone.

The same sequence as that which has been just detailed may be traced still more towards the east along the coast of France, and even reaches to the Bas Boulonnois. In this district there is an imperfect development of the Oolitic series, commencing with a limestone containing the *Gryphæa virgula*, and representing the lower part of the Kimmeridge clay. Over this is a bed consisting chiefly of the cemented fragments of shells, and this again is surmounted by a sandstone, probably the Portland sand.

II. The Oolites of the Jura.



SECTION ACROSS THE JURA CHAIN, NEAR PORRENTRUY.*

As it is from the mountain range of the Jura that the continental strata of the Oolitic period have derived the name by which they are best known, ("*Terrains jurassiques*," "*Jurakalk*,") and as from the types there presented most of the continental synonyms of the different subdivisions have been derived, it will be necessary to explain the general conditions of the deposit in that part of Europe, and the relation which the various strata bear to the well-known beds which characterise our own island.

The Jura mountains form a group separated from the High Alps by the great valley of Switzerland, and the principal elevations follow a direction nearly parallel to

* 3. Coralline limestone.
2. Argile d' Oxford.
1. Oolite inferieure.

those of the Alps, or north north-east, and south south-west. Towards the north of Switzerland, however, and where the Jura range approaches the Vosges, the general axis of the former or newer range is turned towards the east, and then becomes north-east and south-west, and even east north-east and west south-west; and in this part, although repeated by many undulations, the whole sequence has been observed beautifully exhibited in some of the picturesque valleys of the district, although the beds are there inclined at a high angle and are occasionally even inverted.

The whole Oolitic or Jurassic system is still, however, divisible into three parts as in England, and the lowermost of them, attaining a thickness of about three hundred feet, is subdivided into four groups of strata, consisting chiefly of limestones, which alternate first with marls and yellowish clay, and afterwards with shaly bands and red oxide of iron, the limestones in the upper part being compact and sometimes lithographic.

The middle Oolites of the Jura, which form a group somewhat thicker than that just described, depart also more widely from the type of Western Europe. They are based upon an argillaceous limestone, (the Kelloway Rock?) and the most important strata of which they are composed consist first, of an oolitic ore of iron, occurring in beds of marl, and constituting about a third of the whole thickness of the group, and, secondly, of a bed called the Nerinæan limestone, corresponding to the coral rag of our country.

Of these beds the one containing the iron ore is worthy of remark from its economic importance, and it has been much worked for a long period. The Nerinæan limestone is, also, an interesting bed, and is so called from a some-

what remarkable fossil with which it abounds, (*Nerinæa*, a genus of univalve shells closely resembling, in external form, the Turritella and Cerithium,) and which is also found not only in the coral rag but in the inferior Oolite in England.

The upper Oolites of the Jura approximate much more nearly than the other parts of the system to the Kimmeridge clay and Portland rocks. The former bed is represented with some accuracy by the greyish schistose marls containing the *Gryphæa virgula* (page 374); but here, also, there is a singular prevalence of iron, and about forty feet of strata, in which pisolitic ore of this metal abounds, appear to be intermediate between the 'gryphæa virgula' marls, and the overlying limestones called *Portlandien.* This apparent peculiarity, however, seems to be owing chiefly to the action of some cause by which the iron has been separated from the mass, and accumulated in a bed, instead of being left disseminated. Throughout the whole series the limestones predominate greatly over the argillaceous beds, and this appears to be still more the case in the Jurassic district of the mountain chain of the Alps.

III. The sequence in the north and centre of Germany is nearly the same as in the Jura, except that the subdivisions are not so strongly marked, and that instead of the Kimmeridge clay immediately resting upon the Nerinæan limestone, there occurs a bed of great economical importance, namely, an exceedingly fine-grained fissile limestone of a rich cream colour, and abounding in fossils, chiefly found in the north of Bavaria, near the towns of Solenhofen, Pappenheim, &c., and exported to most parts of Europe for the purposes of lithography.

But the Jurassic formations of Franconia are not less

SECTION NEAR SOLENHOFEN *

celebrated for the vast caverns with which some of their limestones abound, and for the singular way in which the cavern district is intersected by deep valleys, than for the important band of lithographic stone which rests on the stratum so singularly honey-combed. The origin of the cavernous nature of this limestone is a point which I shall not here discuss. The bed is dolomitic, and is, probably, contemporaneous with the newer beds of the coral rag. Some idea of the position of the lithographic limestones with respect to it may be obtained by examining the accompanying section; and I need only observe concerning these beds, that there is abundant evidence of their having been very slowly deposited, the remains even of insects being accurately preserved in them, and the markings of the nervures of the wings perfectly retained. In other fossils obtained from the same locality, a beautiful example of which is figured in the annexed engraving, the antennæ and other parts of crustaceans are so distinctly impressed upon the stone, that their minute structure may be distinctly observed with the aid of a magnifying glass.

IV. A considerable portion of the great chain of the Alps, and other mountains of Europe connected with their elevation, unquestionably belongs to the Oolitic pe-

* 4. Compact lithographic slate.
3. Dolomitic limestone.
2. Compact limestone. Coral rag.
1. Fine sandy beds. Lower oolites.

ERYON ARCTIFORMIS.

(*Solenhofen Lithographic Slate.*)

riod, but the difficulty of accurately determining the subdivisions is almost insuperable, owing not more to the violent contortions and disturbances that have affected them, than to the absence of fossils, which have in most cases been destroyed by the action of subterraneous heat.

Difficult, however, as it is to make out satisfactorily this singular and complicated chapter in European Geology, it appears clear that the sedimentary rocks, which are found resting on the great mineral axis of the Alpine chain, belong to the Oolitic system, or to the subjacent beds of the Lias. But it would not be consistent with my plan to dwell at all on the detail of a country like Switzer-

land, in which almost all geological phenomena presented to view are difficult and complicated in the very highest degree; and I must refer to M. Elie de Beaumont, and the account of his and other researches, for even the outline of what is known on this subject. It is enough that the conclusions arrived at are in perfect harmony with what was already known of the strata and their disturbances.

V. The beds contemporaneous with the Oolites in the north-east of Europe have almost entirely lost the "Oolitic" character, and present lithological analogies rather with the Lias than any other bed. True Lias, however, seems not to exist in Russia; but the whole Oolitic series is divided into two stages, the lowest of which, though much more developed than the upper, is distributed in patches, and does not occupy any considerable tract of country. It is, notwithstanding, very consistent, preserving the same mineral and fossil characters from the eastern flanks of the Ural chain (in north latitude 64°) to the Caspian Sea. The upper group occurs in several spots along the Donetz, and is calcareous, oolitic, and of a light yellow colour. In the south of Russia, where the beds are chiefly of this character, they are charged with large Ammonites, and other shells like those of the Coral rag and Portland rock.

In the Caucasus it appears, from the recent researches of M. Dubois, that the central ridges, formerly supposed to be primary, are of the Liassic and Jurassic periods; and although assuming lithological aspects of the most ancient character, and pierced through by porphyries, which have also elevated some of the strata ten thousand feet above the sea level, there is now no doubt of their contemporaneity with the quietly deposited and undisturbed rocks of our own country, which have been simply elevated to be-

come dry land, but in many places have hardly lost their horizontality.

Researches such as those of M. Dubois in the Caucasus are the means by which we may hope ultimately to connect, in a satisfactory way, the Geology of the East with the well-known English and European types; but, at present, this is no easy task; nor does the discovery of a few shelly bands in a particular district enable the Geologist to identify important groups of strata in far distant lands. That fossils, however, indicative of almost all the really important subdivisions of the Middle Secondary Period do exist in various parts of Asia, and more especially in the peninsula of India, and on the flanks of the Great Himalayan chain, there is, perhaps, little doubt; but much is still wanted to complete even a local knowledge of the different beds, and much more before they can be safely identified with contemporaneous ones in Europe.

One of the most important memoirs, containing a detailed account of the Geology of Secondary formations in Asia, describes the structure of Cutch, a district in North Western India, situated between 22 and 24 degrees north latitude and 68 and 70 degrees east longitude, and stretching towards the east from the eastern branch of the Indus. This district would appear to possess a series of formations contemporaneous with the Oolitic group,* and the lowest stratified bed (resting on Syenite and quartz rock) consists of sandstones containing thin beds of coal, alternating with shales and occasional bands of ironstone. Several beds of coal have been discovered, but they do not appear to be sufficiently thick to be worth working. The fossil vegetable remains obtained from them, although not identical, are strictly analogous with those of the English Oolites,

* See Capt. Grant's Memoir, Trans. of Geol. Soc. 2nd Ser. vol. v. p. 290.

and have been referred to a genus scarcely removed from Zamites*. A red sandstone, containing no fossils, immediately overlies these carboniferous deposits conformably, and is covered up by other strata, in which a considerable amount of calcareous matter appears interstratified with argillaceous beds and sandstones, many of the calcareous slabs being compact and formed of a grey limestone, which takes a good polish, and might be employed for lithographical purposes. These newer beds are for the most part horizontal and not conformable with the underlying sands, which have a variable dip, and have been greatly disturbed. The series is closed by a compact, crystalline sandstone, sometimes changing into a coarse soft sandstone, much of which appears to have been denuded. The evidence of fossils is sufficient to place the whole series among the middle and upper secondary groups, but the exact position is not yet defined.

With regard to North America, there seems to be a remarkable absence of all rocks of the Middle Secondary period throughout that vast continent, and the transition from the New red sandstone to the greensand and other rocks of the Cretaceous period is abrupt, so that it seems almost impossible that there can be any representative of the Oolitic series.

* *Loc. cit.* Explanation of Plates.—Plate 21.

CHAPTER XXVI.

THE FOSSIL PLANTS AND INVERTEBRATED ANIMALS OF THE OOLITIC PERIOD.

SHELLS FROM THE GREAT OOLITE.

Minchinhampton.

a. Pileolus plicatus.
b. Phasianella. n.s.
c. Trochotoma sulcata. Sow. (?)
d. Rostellaria. n.s.
e. Purpura (?).

In the great series of rocks grouped together under the general term *Oolitic*, but which vary in every important point, as well of mineral and lithological character as of circumstances of deposition and association, it may well be imagined that the fossil remains found embedded are also of various kinds, and indicate many different conditions of animal and vegetable life. Indeed the large number of

the species, of whose existence during that period we have certain knowledge, is hardly less remarkable than the extremely wide range in the animal and vegetable kingdom over which these species extend.

As a preliminary remark with regard to the vegetable remains of the Oolitic period, it may be well to remind the reader, that, in the Secondary formations generally, there are no true coal-fields; and that, although (as is the case at Brora, and in the Kimmeridge clay, near Weymouth,) there may be considerable deposits of carbonaceous matter, the vegetable remains in those deposits are only in the condition of imperfect lignite, more or less bituminised, and never so much so as to be really valuable for continued working. But, notwithstanding the absence of true coal, numerous fossil remains of vegetables are met with in the sandstones and shales of the Oolitic series, and especially in the lower Oolites in the north of England, (at Scarborough and Whitby,) in the Stonesfield slate, in some beds of the coral rag, and in the Portland beds. The species obtained from all these various localities differ essentially from those of the Carboniferous rocks; and they form, on the whole, an intermediate group, indicating, to a certain extent, the nature of a gradual change that seems to have taken place in the passage from the flora of the Palæozoic period to the more recent types of vegetation.

The fronds of ferns, referrible to several genera common in the Carboniferous rocks, are again met with in the older beds of the Oolites, though not so frequently as in the Keuper marls and other beds of the New red sandstone; but the leaves of another family of plants, the Cycadeæ, whose remains occur for the first time in the New red sandstone, now greatly predominate; and the Zamias and others of that tribe seem to have replaced the Lepidodendron, Sigillaria

and Calamite, which, with the exception of the latter, are entirely absent.

The Cycadeæ form a beautiful family of plants not now indigenous in Europe, but still living in tropical and southern latitudes. They resemble the palms in external habit; they approach in several essential characters of internal structure to the Coniferous tribe, while, at the same time, they offer striking analogies with the ferns, in the mode in which the leaves are curved up at their extremities within the buds. These analogies are not a little interesting to the Geologist, as the fossil Cycadeæ abound chiefly, as I have already observed, in formations intermediate between the Carboniferous rocks,—the great storehouse of the ancient forms of vegetation,—and the Tertiary strata, whose vegetable fossils strikingly resemble the plants now living on the earth. Of the various recent Cycadeæ, the Cycas and the Zamia are those which, perhaps, offer the most marked resemblances to the extinct species.

The Cycas, when growing under favourable circumstances of temperature and moisture, usually presents a magnificent crown of graceful foliage, surrounding the summit of a simple cylindrical trunk, like that of a palm, and sometimes attaining a height of thirty feet, but usually much shorter. This trunk possesses no true bark, but is surrounded by a dense case, composed of persistent scales, which have originally formed the bases or points of attachment of fronds, and which, together with other abortive scales, form a compact covering, supplying the place of bark.

Extinct species of this family are found very abundantly in various Oolitic strata; and the cylindrical stems are especially common in the Portland beds, where they are well known to the quarrymen under the name of

petrified birds'-nests, to which indeed their external form bears a rude resemblance. They are usually silicified, (their mineral condition varying from coarse granular chert to imperfect chalcedony,) and the specimens are of very different dimensions, but are most commonly short, flat, and nearly of the form and size of a recent species of Zamia (*Z. horrida*). No leaves have ever been found adhering to the stem; but in the same beds peculiar fern-like fronds, resembling those of recent Zamias, have been frequently met with, and the bases of similar leaves are seen to rise upwards in the fossil, and are most perfect near the summit of the trunk. A cavity is usually visible at this summit, the origin and use of which is known by referring to the recent plant, where the crown of leaves surrounds the margin of the cavity, and this latter is filled by a cluster of fronds producing the fruit.

OTOPTERIS ACUMINATA.
Var. brevifolium.
Whitby.

On a minute and microscopic examination of the fossil Cycadeæ, as well as from their general appearance and mode of growth, they appear to be closely allied by many remarkable characters to the existing species; and these resemblances have reference,—(1) to the internal structure of the trunk, which, in both cases, contains radiating circles of woody fibre, embedded in cellular tissue:—(2) to the structure of the outer case, (which replaces the bark of other trees,) and the minute details of the internal organisation of each petiole or leaf-stalk, and (3), to the mode of increase of the plants, which is by buds protruding from

germs in the axillæ, or angles at which the leaf-stalk unites with the stem.

With regard to the particular genera, that which is best known under the name Cycadites,* and which is so common in the Portland-stone, appears to approach more nearly than any other to the existing genus Cycas, but possesses a more perfect structure of dicotyledonous wood, and in this respect holds a higher rank in the scale of vegetable creation.

The leaves common in the middle and lower Oolitic strata usually belong to other species of the same genus, or to other genera very closely allied (see figure p. 386); and they all appear to agree in indicating the former existence of warmer climates in our latitude, or at least of a temperature and atmospheric condition somewhat resembling that of the islands in the southern seas, which offer many marked differences of animal as well as vegetable life, when compared with the fauna and flora of any land at similar latitudes in the northern hemisphere.†

* This fossil genus has been described under various names: *Cycadites* was given by Brown, *Mantellia* by Brongniart, and *Zamites*, which is perhaps the proper, as it is certainly the oldest name, by Count Sternberg. Cycadites is, however, that most familiar to English Palæontologists.

† It is a favourite speculation of some Geologists, that there has been a considerable diminution in the general average temperature of the globe. It may be so; but, so far as these conclusions are made to rest upon the supposed resemblance of the flora of the Carboniferous and Secondary periods to that of tropical climates, I would earnestly direct the attention of the reader to the botanical condition of New Zealand, a botanical centre in a latitude the same as that of a great part of Europe.

In the island of New Zealand it is said that there are only 632 species of plants known, and that probably not many more will ever be added to the list. Of this number more than one-half are monocotyledonous, and 245 of them cellular or flowerless plants. With regard to distribution, the ferns and fern-like plants are by far the most numerous, covering immense districts, replacing the grasses of other countries, and giving a character to all the open land, whether hill or plain. Some of these ferns grow to thirty or forty feet in height and in groups, and there is an astonishing variety and elegance in their forms, from the

The remains of plants, not so much indeed by the mere fact of their occurrence as by the condition in which they are found, offer sufficient proof of the near presence of land in those seas in which the deposit of the Oolitic strata took place; and that such land consisted of small detached islands we may, perhaps, fairly conjecture, from the character of the fauna, as exhibited in the fossils obtained from the various beds. These are chiefly the remains of marine animals, and throughout the whole sequence they have a uniform character, and the different species pass, by insensible gradations, into one another.

The Fauna of the whole Oolitic period cannot, indeed, be looked upon, on the one hand, as composing a single group; nor, on the other hand, in the gradual substitution of species as we successively examine the newer beds, is it easy to draw any decided line, or assert that certain extinct species are strictly confined within assigned limits. No doubt there is a wide and strongly marked difference between the fossils of the Lower or Great Oolite, and those of the Portland stone; and the existence of forms, which attained their maximum of development in newer formations, is only just evident in the older ones; but the difficulty of separating them still remains, and is greatly in-

most minute species to the lofty giants of their tribe. On the other hand, so scantily distributed are the grasses that, near the coast, they are only found as rare specimens, and even in the interior it is only on barren volcanic table-lands that they are more numerous than the ferns.

The most valuable timber in these islands belongs to the Coniferæ, which, with the palms and tree-ferns, form the prominent objects in the forest scenery. The trees are covered also with climbing plants, one of which belongs to the family of the *Pandaneæ*, or Screw Pines. See Dr. Dieffenbach's Travels in New Zealand. Vol. i. p. 419, *et seq*.

The resemblance of this vegetation to that of the Carboniferous and Oolitic periods, as exhibited by their fossil remains, is too remarkable to be passed over in silence. I have figured in various places as vignettes specimens of New Zealand vegetation, which will in some measure help to illustrate this subject, (see vignettes, pp. 266, 355, 370, 401, &c.)

creased by the fact, that some species of animals* of very high organization seem to be continuous throughout the whole of the series, commencing even with the Lias and passing into the Wealden strata. It is only by comparing extensive series of fossils, the species in each group being obtained from the same locality, that any really valuable conclusions can be arrived at with reference to an entire formation; and at present there are few instances of such groups being collected, or so carefully and completely named, as to be referred to with advantage.†

Perhaps, therefore, it will be on the whole most instructive and interesting to give a general view of the extinct species of the Oolitic period, chiefly with reference to the different natural families to which they belong, and mentioning only the localities of the more remarkable fossils.

The corals of the Oolites are chiefly met with in the Middle Oolitic beds of our own country, and in the beds of the same or a somewhat earlier date on the Continent. The coral rag in the south of England (at Steeple Ashton

* *E. g.* Ichthyosaurus communis, which is said to have been found throughout nearly the whole Secondary series.

† It must also be remembered, that the fossils found in argillaceous deposits will necessarily differ much from those in calcareous beds, owing to the circumstances of deposition; and in this way two very different groups may be obtained from nearly the same Geological horizon. Thus, from the Bradford clay, and the great Oolite, two beds nearly contemporaneous and both highly fossiliferous, the species will differ more than between other beds possessing the same mineral character, although separated by many feet of fossiliferous strata. I would direct the special attention of the reader who feels interested in the discussion of this subject, to an extremely interesting report recently drawn up by Professor Edward Forbes "on the distribution of the Mollusca and Radiata of the Ægean Sea, considered as bearing on Geology." I think, however, that it will be more advantageous to postpone for the present the consideration of the important generalisations to which this "Report" (published in the Thirteenth Report of the Meetings of the British Association,) necessarily leads, and I shall recur to it in a future chapter, when the subject of the Zoological changes which have taken place during the Secondary period will be treated at some length.

in Wiltshire,) is exceedingly rich in fossils of this kind; and it appears not improbable, that the whole formation exhibits the remains of an ancient coral reef, in which some few species, (among which the *Caryophyllia annularis*, see figure *a*, p. 365, was, perhaps, most abundant,) very greatly predominated, and accumulated a large proportion of the solid rock.

The Caryophyllia, so abundant in the coral rag, belongs to the tribe of Madrepore corals, a tribe of which the different species still rank as amongst the most remarkable for their activity in building coral islands and reefs in the existing tropical and southern seas. The other corals figured in the cut, page 365, are met with in continental localities, and they belong to a different group. They are, however, common and characteristic.

Passing on next to the Echinodermata, we find almost all the various genera of that class represented in some one or other of the Oolitic strata. The star-fish, and the sea-urchins, are common in all the calcareous beds with the exception of the lithographic limestone, and are there replaced by the *Comatula* and the *Ophiura*. The clays, or at least thin beds alternating with them, contain the still more singular remains of Encrinites, of which the Apiocrinite, or Pear Encrinite of the Bradford clay, is that most interesting to the Palæontologist.

As I have already described both the Lily Encrinite of the Muschelkalk, and the Pentacrinite of the Lias, I shall not now dwell at length on the peculiar structure of the Apiocrinite. Its remains are found in incredible abundance, and often very perfect, and it is an object of great interest to local collectors, from its picturesque form and grouping, fragments of several individuals being often found together, proceeding from the same base.

Unlike the Pentacrinite, the Apiocrinite was an animal firmly and permanently attached to rocks at the bottom of the sea; and this attachment took place by an expanded stony base, many specimens of which are found covering the Oolitic rock which immediately underlies the Bradford clay. The column seems to have been of moderate length, and was formed of numerous round joints, pierced in the centre for the passage of an alimentary canal. On the uppermost joint a calcareous body was placed, of an elegant pyriform shape; and in this is a hollow space, produced by the gradual enlargement of the aperture of the stony plates, corresponding to their increased dimensions.* The soft parts of the animal were placed in this hollow space, and around it, on all sides, a number of arms arose, one pair proceeding from each of five pentagonal plates, which form the uppermost row of those enclosing the pouch. From each of these ten arms, other smaller arms, or tentaculated fingers, as they are called, take their origin, the fingers expanding like an opening flower when the animal was in search of its prey, or remaining contracted and closed (as in the figure) when in a state of repose.

APIOCRINITES ROTUNDUS. MIL.

Bradford clay.

* This will be best understood by referring to the figure, in which a portion of the column and body is represented in section.

Other extremely elegant forms of Radiated animals are characteristic of some of the Oolitic strata both in England and elsewhere. Among the most elegant of these, perhaps, is the *Eugeniacrinites*, a figure of which is given in the next page. The animal appears to have been somewhat less perfectly provided with arms and fingers than that we have just been describing, and was also of smaller size; but it rose in a similar manner from a strong stem, and was likewise attached to the solid rock.

As of somewhat higher organization than the attached Crinoidal animals, such as the Apiocrinite and Eugeniacrinite, we may next allude to the *Comatula* of the lithographic slate, and the *Ophiura*, also common in the same stratum. The former of these genera is more especially interesting to the Palæontologist, as occurring in a recent state, and passing through the condition of a fixed Pentacrinite in the early stages of its development, although it afterwards becomes, by a final metamorphosis, a free-swimming star-fish.

The *Ophiurella* is remarkable for its long slender serpent-like arms appended to a depressed body, like that of a sea-urchin: the number of the arms is five, and they are regularly radiated.

OPHIURELLA CARINATA.
Solnhofen slate.

The genus *Goniaster* (the Cushion-star) is a link connecting the true star-fish with the sea-urchins, and is represented by several species in various beds of the foreign Oolites. Like other star-fishes, the skeleton is made up of small pieces of carbonate of lime, many hundred in number, which are variously dis-

posed, and fitted with great accuracy, forming a rude network of solid particles, upon the exterior of which the cutaneous appendages of the animal are fixed.

RADIATA OF THE OOLITES.

b. Cidaris coronata, SCHLOT. *c, d.* Eugeniacrinites caryophyllatus. GOLDF.
a. Disaster (*Spatangus*) carinatus, AG.

Lastly, the Sea-urchins, or Echini, and the genera Cidaris and Spatangus, which are nearly allied, are abundant in several parts of the Oolitic system; and some of them are common both in the upper and lower beds. The shells, if they may be so called, of these animals are built up of numerous pentagonal plates, constituting a hollow spheroid; and each plate is perforated for the passage of tubular feet, or provided with a projecting ball, on which a solid spine is attached, movable by a ligament passing through an aperture in the ball. In these singular animals nearly the same spheroidal figure is retained from their earliest formation to maturity, the calcareous plates of which the hollow globe is made up receiving constant additions to all their margins, so that the shell gradually expands with little change in its relative proportions.

It is in the upper members of the Oolitic group that the Palæontologist first meets with remains of Crustacean animals and insects, which bear any close analogy to existing forms of those animals; and the resemblance is

often so striking, that it is difficult, if not impossible, to separate some genera from their closely allied recent analogues. The lithographic limestone of Solnhofen contains the most remarkable of these,* and beautiful and perfect as many of the specimens are, they differ so little from existing forms as hardly to admit of any general description which shall mark their difference from well known species.

The Crustaceans of the Solnhofen slate have been frequently described, and are well known, and their variety and the perfect condition in which they are found is unequalled in any other bed. I have figured one species, an *Eryon*, see page 379, from the extensive collection of these fossils in the Geological Museum of the University of Cambridge, and I might have selected very many others equally well preserved, and equally characteristic of the formation.

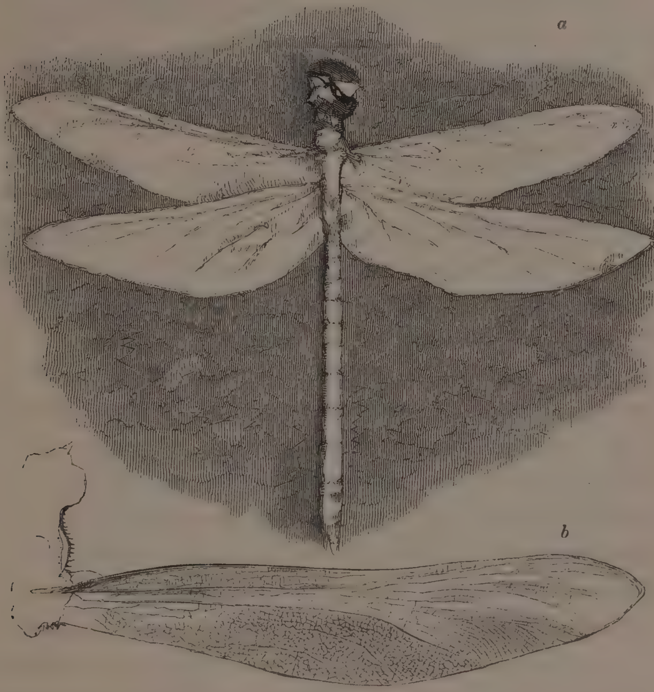
The genus Eryon belongs to the family of Macrourous Decapods, and was aquatic, and no doubt marine in its habits. It belongs to a subdivision containing the crayfish, lobster, &c.

Of the genus *Limulus*, or King Crab, there are also several species in the Oolitic strata, and these are the more interesting, because, according to Professor Owen,† "the Limuli form the only genus of large Crustaceans represented by species which co-existed with Trilobites." These animals differ from other living Crustaceans in their organs of mastication, the office of jaws being performed by the first joint of the thoracic legs which surround the mouth. The last segment of the body forms a long

* The wing cases of beetles, and even the wings of neuropterous insects are also found in the calcareous flagstone of Stonesfield.

† Lectures on the Invertebrata, p. 176.

three-edged sharp-pointed weapon. The eyes are large and compound, and the cornea is subdivided as in the Trilobites.



a. ÆSCHNA MUNSTERI. Germ.
b. WING OF LIBELLULA LONGIALATA. Munst.

Solnhofen slate.

The insects, of which two specimens are figured in the annexed cut, resemble very closely the common Dragon-fly, both in form and in the markings of the wings. They are, however, considered to be generically distinct.

The remains of these Crustaceans and insects are not confined to the calcareous strata of the Oolitic series, but are found also in the Oxford clay. We shall after-

wards see how interesting this fact becomes with reference to the other fossil remains from the same bed belonging to animals of higher organization.

Let us now turn to the remaining Invertebrata—the Mollusca—by whose means we may trace in the fossils of the Oolites a complete chain of existences, connecting the animals of lowest organization with the more complicated Vertebrata.

Of the subdivisions of the Mollusca, we shall find the *Acephala* (a division including the animals of most bivalve shells, and all those common in our own seas,) represented in almost every fossiliferous bed of the Oolitic series, and by species which more or less resemble those still existing. The Pteropoda, Gasteropoda, and Cephalopoda have also left abundant remains which are not less characteristic.

The *Terebratula*, the only genus now remaining of the Brachiopoda, is also the only one met with among the Oolitic fossils. It is very abundant in particular localities, and is represented by about fifty species. It appears probable, that the animals of this genus, during the Oolitic period as at present, inhabited the deeper waters, creating a perpetual current by means of their cirriform appendages, and thus dissipating the water rendered unfit for the purposes of life, and also bringing within the reach of their prehensile organs the animalcules adapted for their sustenance.*

Species of Acephala, allied to the ordinary bivalve molluscs, are found in almost all the principal beds of the Oolites, and the nature of the groups in different localities seems to have depended on the mineral character of the deposit, the depth of the water, and the condition of the bottom of the sea, at the period of those deposits, as it

* Lectures on the Invertebrata, p. 279.

is known to do at the present day. Several genera of the family Myaceæ are found,* the inhabitants probably of sandy beaches and mud; at least fifteen species of *Trigonia* (see p. 362), a genus only represented by one or two known species in the seas which wash the shores of Australia; together with *Ostrea*, *Pecten*, *Cardium*, and other allied genera, all attesting the resemblances that existed to the fauna of more recent times; while in several of the univalve shells we are presented with forms still common, associated with others since extinct, although then so abundant as to make up whole beds by the accumulation of individuals of the same species.

a. PHOLADOMYA FIDICULA. Sow.
b. CARDIUM LUNULATUM.
c. PLEUROTOMARIA.

Lower Oolite.

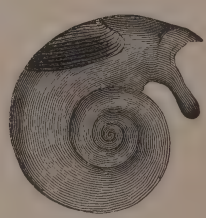
Thus the *Nerinæa* is a genus resembling both Cerithium and Turritella, but the shell is thickened at the mouth so as to present a singularly anomalous appearance in a section: the *Pleurotomaria*, and *Trochotoma* are shells like the Trochus but having, the one a longitudinal fissure, and the other an occasional aperture, probably connected with the breathing apparatus of the animal; and these with several other extinct genera abound in particular lo-

* E. g. *Pholadomya.* See figure (*a*).

calities, the latter being most common in the strata of the Lower Oolites*, and the former (Nerinæa) giving its name to a limestone of the date of the coral rag.

Throughout the whole series of these rocks the remains of Cephalopoda, chiefly Ammonites and Belemnites, are also abundant, and have been admirably preserved; and in one of the Oolitic beds (the Oxford clay), specimens of each genus have been found, tending to clear up the obscurity that long prevented a satisfactory account being given of the animal inhabiting those shells, and exhibiting, in the case of the Belemnite, not only the shell itself in its most perfect and uninjured state, but also the marks of the soft parts of the animal, even to the impression of the head, the eyes, and the tentaculæ.

Referring to what I have already said on the subject of the Ammonite and the Belemnite, while speaking of the Invertebrata of the Lias, and taking up the subject as it was left after a careful study of the Lias specimens, let us now consider the additional facts that have been made out since the Oxford clay has been the object of similar careful research.



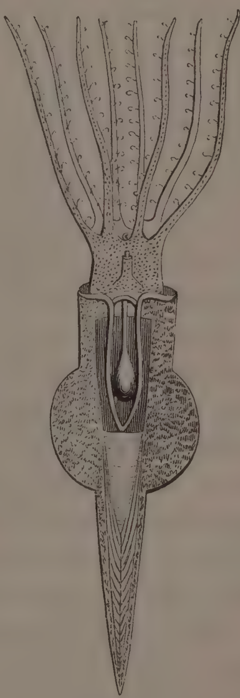
AMMONITES SEMICANALICULATUS.

Solnhofen slate.

Not only in the Oxford clay, but also in the lithographic limestone, the remains of Ammonites have been found sufficiently perfect to give the most distinct outline of the termination of the aperture. It has thus been found, that, in some species, a long narrow process projects from each side of the aperture, indicating a cor-

* See the figure of fossil shells of the great Oolite at the commencement of this chapter, p. 383.

responding modification of the lobes of the mantle, and not unlike the appendage projecting from the mouth of the Argonaut. Sometimes, again, the full grown shell seems to have been arched over transversely by a plate of calcareous matter, and not unfrequently there is found within the outer chamber a singular shell-like body, called *Aptychus*, whose nature has not yet been explained.* In no instance, however, has any trace of an ink-bag been seen, and it is probable that, in this respect, the Ammonite resembled the Nautilus, and was unprovided with such a means of escape from its enemies.



BELEMNITE.
(*Restored outline.*)

It is only within a very short time that absolute and decisive proof has been obtained of the nature of the actual shell of the Belemnite, and of the way in which it was covered and enclosed by the mantle of the animal. A specimen now exists in the Museum of the Royal College of Surgeons, " in which not only the ink-bag, but the muscular mantle, the head, and its crown of arms, are all preserved in connection with the Belemnitic shell. It appears to have been the peculiar property of the matrix (a member of the Oxford clay formation,) in which this and many similar valuable and in-

* One of these singular fossils is represented in the outer chamber of the Ammonite (A. semicanaliculatus) in the annexed figure.

structive specimens were entombed, to favour the conversion of the muscular tissue into adipocire and its subsequent preservation to the present time." * A second specimen less complete, from the collection of Mr. Pratt, exhibits the contour of the large sessile eyes, the funnel, a great proportion of the muscular parts of the mantle, the arms, or tentaculæ, armed with a double alternate series of horny hooks, and the remains of two lateral fins: these latter being situated on each side of the visceral cavity, and presenting the form of flattened, transversely-striated, fibrous masses, with their free border entire and rounded.

Thus, at length, the whole anatomy of the Belemnite is made out, and we learn from ocular evidence, that it combined the characters of three distinct genera of Cephalopoda, possessing a calcareous internal shell like that of the *Sepia*, the formidable hooks of the arms which characterise the genus *Onychoteuthis*, and the limited attachment of the lateral fins to a position a little in advance of the middle of the body, as in the *Sepiola*.

It is by the careful investigations of Professor Owen that these interesting points in the anatomy of an animal long since extinct have been made out, and I shall conclude this chapter with his admirable description given in the work already quoted. "The Belemnite," he there observes,† "having the advantage of its dense but well-balanced internal shell, must have exercised its power of swimming backwards and forwards, which it possessed in common with the modern Decapod Dibranchiata, with great vigour and precision. Its position was probably more commonly vertical than in its recent congeners. It would rise swiftly and stealthily to infix its claws in the

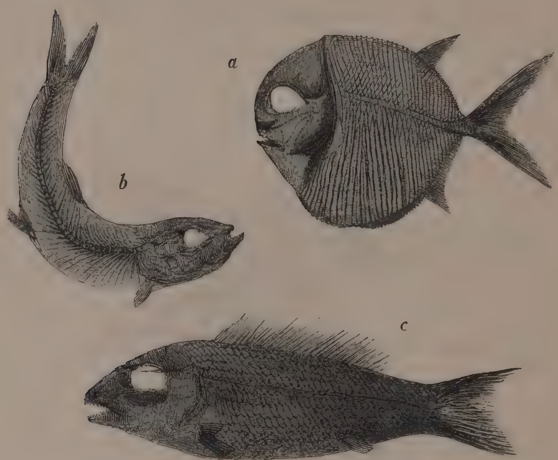
* Owen's Lectures, &c. p. 337.

† *Loc. cit.* p. 339.

belly of a supernatant fish, and then, perhaps, as swiftly dart down, and drag its prey to the bottom and devour it. We cannot doubt that, like the hooked Calamaries of the present seas, the ancient Belemnites were the most formidable and predaceous of their class."

CHAPTER XXVII.

THE FOSSIL VERTEBRATA OF THE OOLITIC PERIOD.



a. GYRODUS GRACILIS. AG.
b. LEPTOLEPIS VOITHII. AG.
c. NOTAGOGUS DENTICULATUS. AG.

Solnhofen slate.

The lithographic limestone of Solnhofen, so rich in the remains of Crustaceans, Insects, and Cephalopodous molluscs, is not less remarkable for the numerous remains of vertebrated animals found in it, although these, as might have been expected from the essentially marine character of the formation, are chiefly confined to fish. The singular defensive fins already described under the name Ichthyodorulites,* are also met with in the clayey beds of the

* See *ante*, p. 337.

Oolites; and the teeth, scales, palatal bones, and other fragments, more or less perfect, of upwards of fifty species of fishes, have been found in the various Oolitic strata of our own country.

Most of these fish are referred by M. Agassiz to the Ganoid Order, and several of the genera most fully represented and most abundant belong to the Sauroid family of that Order. Other families, and more especially the Lepidoids and the Pycnodonts, contain also several Oolitic species.

Of the Lepidoids, a group comprising fish whose body is fusiform and elongated and the tail forked or rounded, a large number are almost entirely confined to the Secondary period, and it was during the formation of the Lias that they seem to have attained their maximum of development. The Sauroid genera *Thrissops*, *Caturus*, *Leptolepis*, *Megalurus*, and *Aspidorhynchus*, and the Pycnodonts *Sphærodus*, *Gyrodus*, *Microdon*, and *Pycnodus*, make up nearly the whole list of those genera which occupied an important position among the extinct fishes of the Oolitic period.

Of these the *Caturus* sometimes attained a very large size, and its jaws are unusally large, and armed with great conical teeth, alternating with others much smaller. The *Leptolepis* is remarkable for its great abundance, but the species are all of small size; the anterior part of the mouth is covered with small teeth, which increase towards the back of the palate; the scales are small, and one species (*L. sprattiformis*) resembles very much a sprat, or anchovy, in its general appearance. The genus *Aspidorhynchus* is remarkable for its shape, the body of the fish being elongated, and the upper jaw prolonged into a kind of snout which overlaps the lower jaw.

The *Gyrodus* (of which a beautiful specimen belonging

to the Cambridge Museum is figured at the head of this chapter, traced from the very fossil itself,) is one of the Pycnodont fish, whose remains abound in the Solnhofen beds. The leading character of this family consists in a peculiar armature of all parts of the mouth with a pavement of thick round flat teeth; specimens of which occur most abundantly throughout the Oolitic formations.* The use of this peculiar apparatus was to crush small shells and crustaceans, and tough sea-weeds. Most of the genera seem to have been omnivorous, and their rate of progression slow. They have enamelled scales like the Lepidoids, but not of so large a size. In all these fishes the tail is homocercal, or, in other words, is not formed by a continuation of the vertebral column to its extremity, but is attached, as in recent fish, from the last vertebra, and formed of two equal, or nearly equal, lobes.†

The remains of extinct Saurians are abundant in the Oolitic beds, and a considerable number of species have been described by Professor Owen, and are referred by him to as many as twelve extinct genera. This number, however, includes the two genera already described, and characteristic of the Lias, and of each of the rest it will be necessary to say a few words.

The Ichthyosaurus and Plesiosaurus, so abundant in the Lias, extend also through the whole Oolitic series, and even pass upwards into the overlying Wealden beds; but the remains of these animals are rare, and consist chiefly of single bones and fragments, seldom exhibiting, as in the Lias, any important part of the skeleton perfectly pre-

* They have sometimes been called Bufonites, and are often found in the Stonesfield slate in their natural position, although the cartilaginous jaw is gone. They are, however, more commonly met with detached.

† See *ante*, p. 185, note.

served in all its detail. These fragments are accompanied by the remains of another Enaliosaurian, nearly allied to the Plesiosaurus, but much larger, and apparently deprived of its most characteristic peculiarity of structure, the long and singular neck. As this genus approximates the Enaliosaurians still more closely to the crocodilians, it has been named by Prof. Owen, *Pliosaurus.*

The head of the Pliosaurus was of very large size, the length of that portion of the jaw-bone in which teeth are planted being in one specimen nearly three feet, and a tooth measuring upwards of seven inches in length, of which four inches were implanted in the jaw. The teeth are simple and conical, presenting varieties of form as well as of size; they were coated with enamel, and supplied incessantly during the life-time of the animal.

The large head of the Pliosaurus seems to have been attached to the body by a series of short cervical vertebræ closely locked together and of very strange proportions, exhibiting a length of only one inch and a half in a vertebra eighteen inches in circumference, and increasing in breadth and depth, but retaining the same length as they recede from the head. The first dorsal vertebra is, however, double that length, and the general structure of the vertebræ, according to Professor Owen,* corresponds closely to that of the Plesiosaur. In this extreme difference of proportion between the length of the cervical vertebræ and that of the vertebræ of the trunk, the Pliosaurus seems to exhibit a remarkable exception to Saurians in general.

In other respects, and more particularly in the bones of the extremities, there is found the closest resemblance to the Plesiosaur; but these bones are of so enormous a size

* Report of the Eleventh Meeting of the British Association, p. 63.

(one femur, or thigh bone, measuring twenty-six inches in length, and thirteen inches across at the broad part) that the animal must have far exceeded in magnitude any known Saurian, and have rivalled in size the very largest existing Cetaceans.

The remains of this genus have been chiefly met with in the Kimmeridge and Oxford clay, and two species have been determined from these localities.

Of Crocodilian reptiles not less than five genera (*Teleosaurus*, *Steneosaurus*, *Poikilopleuron*, *Streptospondylus*, and *Cetiosaurus*,) are found in various parts of the Oolitic series, and some of them pass upwards like the Enaliosaurs into the overlying Weald. The two first of these genera nearly resembled the *gavial*, or crocodile of the Ganges: the *Poikilopleuron* was a reptile measuring, when full grown, about twenty-five feet in length, and is remarkable for a large medullary cavity in the centre of the bodies of the vertebræ (of which also both extremities are slightly concave); the *Streptospondylus* has the bodies of the vertebræ articulated by a ball and socket joint, as in existing crocodiles, but, unlike them, the convexity is on the anterior part of the vertebra, and the concavity directed backwards; and the *Cetiosaurus* appears to have been a gigantic marine Saurian, provided with webbed feet, and a broad tail like that of the alligator.

The *Teleosaurus* has been chiefly met with in the lower beds of the Oolitic series, but was first described nearly a century ago, from a specimen found in the Upper Lias of Whitby, on the Yorkshire coast. The same species has since been obtained from the Oolite of Caen, and two others, one from Stonesfield, and the other from the Kimmeridge clay.* The most common species (*T. chapmanni*)

* Report, &c. p. 81.

appears to have attained a length of about eighteen feet, of which the head occupied about one-fourth part, and was provided with long slender jaws, armed with a large number of sharp-pointed teeth (amounting to 140). The extremities were smaller in proportion than in the crocodile, and apparently better adapted for swimming than for moving about on land; while the animal was covered with bony scales or scutes, regularly disposed like those of existing crocodiles, the margin of one covering the base of the succeeding scute, and slightly overlapping it also laterally. It is probable that, like the Gangetic crocodiles, this animal fed chiefly, or entirely, on fish, and, as it is observed in the report already referred to, "the modification in the structure of the vertebral column, and the complete mail of imbricated bony scutes, indicate that the habits of the ancient *Teleosauri* and *Steneosauri* were more strictly marine than are those of the modern Gavials, and that their powers of swimming, of pursuing, and overtaking their aquatic prey, were greater."*

The *Cetiosaurus*, of which four species are at present determined, approaches the Enaliosaurians rather than the crocodiles in the great expanse and proportions of the bones of the sternum and pubis (probably corresponding to habits almost exclusively aquatic); but the adherence of the genus to the Crocodilian type is marked by the form of the bones of the extremities, and, above all, by the toes being terminated by strong claws. The tail also, of which several vertebræ have been examined, must have presented the compressed Crocodilian type, and is an additional and useful indication of the Saurian affinities

* Report, &c. p. 73. The two genera differ from one another chiefly in the position of the external nostril, which, in Teleosaurus, is at the extremity of the upper jaw, and in the other genus a little behind and above the termination of the upper jaw.

of the fossil, which the very close approximation of the larger vertebræ to the Cetacean type might otherwise have rendered doubtful. Calculating from the proportions of the vertebræ, it would appear that the larger species of this genus must have attained a length of at least sixty feet; and the structure of the caudal vertebræ, their strength, texture, and vertical compression, proves that the main organ of swimming was a broad, vertical tail. The very large size of the bones of the extremities indicates that the animal was provided with legs, and not paddles; and the legs seem to have been terminated by large webbed feet.* On the other hand, the coarse tissue of the long bones, and the absence of a medullary cavity, show that it was strictly aquatic, and probably marine in its habits. No teeth or fragments of jaws have hitherto been discovered, but the presence of these is not necessary to convince us of the predatory habits of the extinct Cetiosaurus.

Professor Owen has separated a group of three very remarkable extinct reptiles (*Megalosaurus*, *Hylæosaurus*, and *Iguanodon*,) as forming a distinct tribe, for which he proposes the name Dinosauria. The animals of this tribe are described as gigantic crocodile-lizards of the land, characterized chiefly by a large sacrum† of unusual construction, and having bones of the extremities of a large proportionate size, more resembling those of the heavy pachydermal quadrupeds, such as the hippopotamus, than any known reptiles, and indicating the terrestrial habits of the tribe. One of these genera, the *Megalosaurus*, occurs with other

* One of the ungueal phalanges measures five inches in length, and three and a half across its articular base. Report, &c. p. 101.

† The *sacrum* is that portion of the vertebral column near its extremity, to which is attached the pelvis, and on which the bones of the extremities depend for support.

very singular fossil remains in the Stonesfield slate;—the remaining two are confined to the Wealden deposits.

The remains of the Megalosaurus, hitherto found, include so many of the principal bones of the body that, although nothing like a complete skeleton has been met with, enough can be deduced to give a very accurate notion of the form, the proportions, and even the habits of the animal. Among the more important bones we have a large fragment of the lower jaw, containing many teeth in different stages of growth, several vertebræ, a complete sacrum, and several bones of each of the extremities.

As the jaws and teeth of animals are, beyond all doubt, the most characteristic parts of the skeleton, it may be discovered by careful examination of the fragment of its jaw, that the Megalosaurus was a carnivorous reptile, closely allied to some existing lizards; that its head was terminated by a straight and narrow snout, compressed laterally; and that its teeth, indicating clearly its carnivorous habits, are admirably adapted to cut and tear flesh. The form of the teeth, too, exhibits a combination of mechanical contrivances extremely remarkable; and there is a provision for a constant succession of new teeth to supply the loss of the old ones. For this purpose, the new teeth are formed in distinct cavities by the side of the old ones, and towards the interior surface of the jaw; so that each as it grew gradually pushed away the one previously existing there, expelling it by the usual process of absorption, and insinuating itself into the cavity thus left vacant. When young, and first protruded above the gum, the apex of the tooth presented a double cutting edge of serrated enamel; but, as it advanced in growth, its

TOOTH OF MEGALOSAURUS.

direction was turned backwards, in the form of a pruning knife, and the enamelled sawing edge was continued downwards to the base on the inner and cutting side, but became thicker on the other side, obtaining additional strength when it was no longer needed as a cutting instrument.

The vertebræ of the Megalosaurus indicate a more decided departure from the Lacertian type than the mode of dentition; but by far the most remarkable difference occurs in the group of five of these bones, which, anchylosed together, form the sacrum, and which are so characteristic of the tribe of gigantic land Saurians.*

Up to the time, indeed, that these bones were discovered, there had been no instance recorded of any Reptilian animal possessing more than *two* sacral vertebræ; and when first the Megalosaurian remains were described by Dr. Buckland, three of the five were referred to by him as belonging either to the lumbar or caudal series. The whole five, however, properly belong to the sacrum, and they are so contrived as to give an amount of strength and resisting power that must have corresponded to enormous muscular energy and weight; and, as if to give them every possible advantage of position, they are not anchylosed in a straight line, but in a gentle curve, forming an arch, and therefore still better able to support the weight pressing upon them.

All the bones of the extremities are exceedingly large compared with the same parts in existing Saurians, and the cylindrical ones are hollow like those of land animals. The thigh bone and the tibia each measure nearly three feet in

* An elaborate account of this and other parts of the Comparative Anatomy of the Megalosaurus will be found in Professor Owen's Memoir on British Fossil Reptiles already quoted.

length; and thus the contour of the hinder part of the body, raised high above the ground, must have been totally unlike that of any existing Crocodilian; and the large share in the support of the trunk, assigned to the hinder legs of the Megalosaurus, probably made it necessary in that genus, as in the heavy land quadrupeds, that a greater proportion of the spine should be permanently and solidly fastened together, in order to transfer the weight through the bones of the pelvis to the legs. The existence of bones of the foot measuring thirteen inches long is also sufficient proof, that a proportionately large base was prepared for the immense column which the leg would form.

Several bones of the anterior extremity have also been referred—some of them not without doubt—to this singular genus; and its dimensions have been calculated rather with reference to these than to the general anatomy of the animal. This mode of calculation has, however, been objected to by Professor Owen, and with great reason; for it is in the highest degree improbable that in an animal, raised six or eight feet from the ground, there should be a tail as long in proportion to the body as that of existing lizards. To obtain a correct idea of the probable dimensions, it is certainly safest to calculate by the length of the vertebræ and their probable number; and in that way we shall arrive at the conclusion, that the body may have attained a length of twelve feet; and that, assuming it had as many vertebræ as the crocodile, which is perhaps hardly likely, the tail might also have been twelve or fourteen feet long: while, comparing the proportions of the bones of the head with those of the Java Monitor, the nearest analogue, we shall have an additional five feet, making in all nearly thirty feet; and

this measurement is more likely to err on the side of excess than of curtailment.*

Even, however, when we have thus halved the length originally assigned, we shall find that, in attempting to picture to ourselves this strange animal, we must draw largely on the imagination. From the size and form of its ribs, the trunk appears to have been broader and deeper than in modern Saurians; and this monstrous trunk was elevated on legs of unusual length and massive proportions, being raised to a height of several feet from the ground. The long narrow snout and powerful dental apparatus, well adapted to the carnivorous habits of the animal, would render it an object of terror as well as astonishment; and it is difficult for us to appreciate the amount of change that has taken place, since a portion of the spot now called England was an island peopled by such reptiles, whose rivers and marshes were crowded with the aquatic Crocodilians just described, and which was surrounded by an ocean in which the Ichthyosaurus, the Plesiosaurus, the Pliosaurus, and the Cetiosaurus, formed a group of predatory animals never surpassed in fierceness, strength, and voracity.

The remains of the Megalosaurus, whose strange proportions, as well as the structure of its bones, mark it at once as a land animal, have been met with chiefly in the Stonesfield slate; and other fragments, both animal and vegetable, found in that bed, prove that it must have been very near the land during the Middle Oolitic period. The lithographic limestone was also deposited near land, and from it, as well as older beds, we obtain occasionally the bones of another Saurian, of extremely different proportions and habits to those we have hitherto considered, but, if pos-

* Owen's Report, &c. p. 110.

sible, yet more strangely anomalous in form, and departing still more widely from any living species.

I allude to the Pterodactyl, an animal which, when its remains were first discovered, was considered by one naturalist to be a bird, by another a bat, and by a third a flying reptile; this discordance of opinion not being without some reason, since it arose from the actual presence in the animal of characters belonging to each of those three great classes of vertebrata. It fell to the lot of Cuvier to disentangle the web of this confusion, and to explain the structure of an animal of which he himself says, "It is undoubtedly the most extraordinary of all the beings of whose former existence a knowledge is granted to us, and that which, if seen alive, would appear most unlike anything that exists in the present world."

The Pterodactyl, in external form, must have resembled the Chiropterous mammals (the Bats and Vampires); but its snout was much elongated, the eyes very large, and the organs of flight still more powerful, and probably capable of being used in the water, and assisting the animal in swimming. Some of the larger species may have attained the size of a cormorant, but others did not exceed that of a snipe.

Commencing our examination of its anatomy with the structure of the skull, we shall find that, far from exhibiting any resemblance to the bats, it approaches, not only in general proportions, but even in the details of its different parts, the skull of the Crocodile; insomuch that in respect of the small size of the cranium, and its anterior position, together with the enormous prolongation of the snout, the Reptilian analogies are completely preserved. The lower jaw also is that of a reptile, and in it, as well as in the upper jaw, there is found a series of holes, whence

the teeth made their way, as in other Saurians, successively replacing those which were worn out. The number of teeth seems to have been about sixty; they are simply conical like those of the crocodile, but rather larger in proportion to the size of the jaw. The whole of the proportions of the head, at least in the more common species, indicate an animal of great strength, capable either of darting down upon fishes, or preying upon the smaller land animals.

The neck is a part of the Pterodactyl exceedingly interesting; for although it contains only the usual number of vertebræ (seven), it must have been of great length, and proportioned rather to the size and strength of the powerful head we have been describing, than to the small and apparently insufficient dimensions of the body; exhibiting, indeed, in this respect an analogy with birds, and indicating a perfect adaptation of the animal for rapid and long-continued flight.

There is also an unusual provision observable for supporting the large head at the extremity of so long a neck, and bony tendons run parallel to the vertebræ for this purpose; while, on the other hand, in illustration of the perfect mobility possessed by the neck, it is only necessary to mention that, in one specimen (described by Cuvier), the head was thrown back so far, that the base of the skull touched the bones of the pelvis, without any appearance of the bones being in an unnatural position.

The number of vertebræ in the back of the Pterodactyl is as many as twenty-two, including the sacrum; nearly three times the number found in birds. In this respect, and in the thread-like ribs, so unlike the flat and broad plates of bone exhibited in this part of birds, we see the Lacertian analogies; but these change again in the

structure of the tail, which resembles that of birds, and does not comprise more than twelve or thirteen vertebræ.

The bones of the extremity and the locomotive organs are among the most remarkable parts of this singular animal, as they exhibit contrivances for sustaining it during long and rapid flights, quite different from the apparatus that exists for the same purpose in any other species, living or extinct.

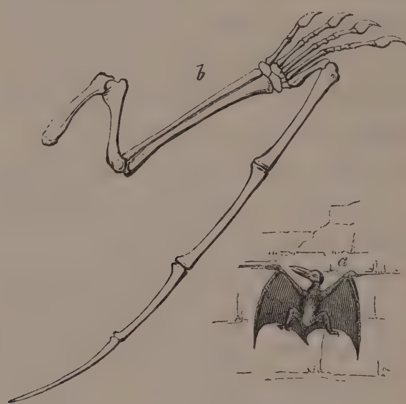
The bones which support the powerful wings of a bird of prey, or any other bird, exhibit, in spite of great external difference, considerable analogies with the corresponding bones of the anterior extremities of quadrupeds, and even reptiles; and it might have been imagined that, in adapting a species of either of these latter classes for flight, and enabling it to live and obtain its prey in the air, similar modifications would have been adhered to. The fact, however, is not so; the wings of a bird are covered with feathers, and to these a great part of their efficacy is owing; but as it did not enter into the plan of nature to provide either Mammals or Reptiles with such appendages, she has resorted to various mechanical contrivances, by which the power of flight is obtained, and the common integument preserved.

In bats, for instance, which are flying quadrupeds, this modification consists principally in the extraordinary development of the fingers, upon which the skin is stretched like the silk on the rods of an umbrella; and this skin extends not merely between the elongated fingers, but also from the last finger to the posterior extremity, and from this to the tail. Of all the fingers the thumb is the only one which is left free, but the toes are exposed, and are moderately long.

In the *Draco volans* again, the only living Reptile able

to support itself even for a short time in the air, there is a kind of imperfect flying apparatus, consisting of an expansion of the skin over a series of false ribs, which extend horizontally from the back; but this membranous wing chiefly acts as a parachute, supporting the animal in its long leaps.

But in the Pterodactyl, a contrivance totally different from either of these is introduced, and it is one which seems to have ensured to the animal the power of walking and swimming as well as flying, a variety of powers unequalled in any other creature.



a. PTERODACTYL, (Restored outline.)
b. P. CRASSIROSTRIS, Right anterior extremity.

In order to effect this, the bones of the fore extremity consist as usual of a humerus, radius and ulna, and carpal and metacarpal bones; and these, as well as the phalanges of three of the fingers and the thumb, are in the usual proportions of a lizard, and correspond with the dimensions of the bones of the posterior extremity, so that, up to this point, there seems no peculiar adaptation for

flying. But on examining yet further we find, that the number of joints or phalangal bones in the last finger (corresponding to our little finger) is increased to five, while each joint is much longer than the corresponding one in any of the other fingers. To the whole length of this greatly elongated fifth finger, the membranous wing or organ of flight was attached, as well as to the whole length of the arm and the body. When, therefore, the arm was extended at right angles to the body, and the fifth finger at right angles to the arm, and parallel with the body, the membrane would be fully expanded; and it appears also to have been fastened to a portion of the hinder leg, and in this way, being nearly surrounded on four sides by bone, the requisite degree of resisting power was obtained. By such a contrivance, the necessity of employing the whole arm in the mechanism of flying, as in the bird, or the whole hand, as in the bat, was done away with: so that, when the wings were not required for flight, the arms and hands could be readily and conveniently made use of, like the corresponding extremities of other animals.

The great peculiarity, then, of the Pterodactyl with regard to this point of structure is, the freedom with which the arms and legs were left to act when the wings were not in use, and this is still more clearly shown by the unequal dimensions of the toes. These organs in the bat form one hook, chiefly useful in suspending the animal at night and during hybernation; but they were so contrived in the Pterodactyl as to allow it to stand firmly on the ground, to walk about like a bird, to perch on a tree, or to climb rocks and cliffs (using the hind and fore-legs conjointly), and possibly also (as its remains are found in marine deposits) to

swim in the sea, and seek its prey among the finny tribes.

To give a general notion of this strangely anomalous creature, I cannot, perhaps, do better than quote, with a few alterations, the description with which Cuvier sums up his account of its Osteology derived from a few specimens laid before him for examination:—

"You see before you," he says, "an animal which in all points of bony structure, from the teeth to the extremity of the nails, presents the well-known Saurian characteristics, and of which one cannot doubt that its integuments and soft parts, its scaly armour, and its organs of circulation and reproduction were likewise analogous. But it was at the same time an animal provided with the means of flying, and, when stationary, its wings were probably folded back like those of a bird, although perhaps, by the claws attached to its fingers, it might suspend itself from the branches of trees. Its usual position, when not in motion, would be on its hind feet, resting like a bird, and with its neck set up and curved backwards, to prevent the weight of the enormous head from destroying its equilibrium. Any attempt, however, to picture this strange animal in a living state, would appear to one who has not followed the whole argument, to be rather the production of a diseased imagination than the necessary completion of a sketch of which the main outlines are known to be true. The animal was undoubtedly of the most extraordinary kind, and would appear, if living, the strangest of all creatures. Something approaching to it in form we may, perhaps, recognize in the fantastic pictures of the Chinese, but art has, in this respect, not been able to rival nature; and the fabled centaur, or dragon, do not present anomalies more

strange than those of the species we have been considering." *

From the same bed (the Stonesfield slate), which contains in England the remains of the Pterodactyl, and in which, also, the bones of that gigantic land Saurian, the Megalosaurus, are found, there have been obtained several fossils (in all the instances fragments of the lower jaw) originally referred by Cuvier to the class MAMMALIA, a conclusion which every further examination has rendered more probable. These remains, however, being the only ones of that order yet discovered in Secondary formations, are possessed of extraordinary interest, and have been described by Professor Owen with minute accuracy, and referred to two extinct genera, *Amphitherium* and *Phascolotherium*, the first in all probability, and the other unquestionably, Marsupial.†

It is not necessary here to speak of the discussions that have taken place on the subject of these fossils, for no one has yet disproved the original assertion of Cuvier, that they offer an exception to the general rule of the absence of Mammalian remains in Secondary formations. They appear to have belonged to small insectivorous Mammals, and one of the genera, at all events, must be referred to the Marsupial order, a tribe of animals now chiefly represented in the island of New Holland.

It may fairly be anticipated that other remains of Mammalia, whether from the same or other localities, may be in time discovered, and throw more light on the points which are still obscure concerning the nature of these interesting animals.

* Ossemens Fossiles. Paris Ed. of 1836, vol. x. p. 248—256.

† See "Owen's History of British Fossil Mammalia," p. 29, *et seq.*

CHAPTER XXVIII.

THE ROCKS OF THE WEALDEN FORMATION.

With the exception of a very few strata, and these exhibited on a small scale, the whole series of rocks we have hitherto considered, from those of the earliest Palæozoic period to the upper beds of the Oolites, bear such evident and decided marks of marine origin, both in their mineral composition and fossil contents, that no reasonable doubt can be entertained on the subject; and this is the case even with the great mass of the Carboniferous strata, almost the only beds which necessarily imply any extent of neighbouring land, but which have never yet offered for investigation the remains of land animals. It is, therefore, with no ordinary interest that the Palæontologist advances to the consideration of the Wealden deposits; as in them, for the first time in the earth's history, he is enabled to examine the nature of the fauna as well as the flora of a considerable extent of ancient land.

The Wealden formation consists of a very thick and varied series of arenaceous beds, based on imperfect limestones, and covered by a bed of clay. The whole series contains the fossil remains of land, freshwater, and estuary animals, and of land vegetables. The group is interpolated between the uppermost beds of the Oolitic group and the lower ones of the Cretaceous series; but it offers so many analogies with the former in the nature of its

fossils, and passes so insensibly from it, that it has often been considered a member of the great Oolitic system.*

The following is a tabular arrangement of the different beds in descending order, as they are observed in various parts of the south-east of England.

3. *Weald clay*, with subordinate limestone (called Sussex marble,) and sand.
2. *Hastings sand*, including the beds of Tilgate forest.
1. *Purbeck strata*, consisting chiefly of compact limestone alternating with clay, and resting on fissile limestone and the Portland beds.

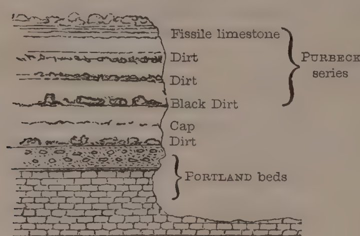
I. Purbeck strata.—It has already been mentioned, that a bed of vegetable mould containing the silicified trunks of trees in the Portland Oolite affords incontestable proof that, towards the close of the Oolitic period, some beds of that series were elevated above the level of the sea; and the fact that this same dirt bed is sometimes met with inclined at a considerable angle, and covered up by other still newer strata, is also sufficient proof of changes then going on, and that a partial depression took place accompanying, however, an elevation which formed land during the period immediately subsequent.

At any rate it is here (in the Isle of Portland) and along the adjacent coast of Dorsetshire, as far as the

* Dr. Mantell, to whom we are indebted for the most detailed account of this formation, describes it as "a series of clays and sands, with subordinate beds of limestone, grit, and shale, containing fresh-water shells, terrestrial plants, and the teeth and bones of reptiles and fishes; univalve shells prevailing in the upper, bivalves in the lower, and Saurian remains in the intermediate beds; the state in which the organic remains occur, manifesting that they have been subject to the action of river currents, but not to attrition from the waves of the ocean."—Geology of the South-East of England, p. 180.

Isle of Purbeck, that the history of the Oolitic strata connects itself with that of the Wealden deposits, and we must search in this neighbourhood for the first transition to strata of unquestionably fresh-water origin.

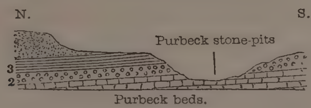
The subjoined diagram represents one of the Portland quarries, and illustrates this arrangement. It exhibits a portion of the Portland rock which has been quarried,



QUARRY. PORTLAND ISLAND.

and the series of beds immediately superjacent; and these latter differ so little from one another, that it may sometimes be doubtful whether any particular one should be considered as Portland or Purbeck, or in other words, as belonging to the Oolitic or Wealden series. As an instance of this may be mentioned the limestone marked 'cap,' which, though non-fossiliferous, has an appearance of freshwater origin, and overlies a dirt bed containing the remains of Cycadeæ, but which, nevertheless, is included in the Portland series. When the line of junction is fairly passed, the first bed that requires particular notice is a fissile limestone, about ten feet thick, and containing fresh-water fossils. This bed, though varying in thickness, is tolerably persistent, being found in the Isle of Purbeck, and again in the Vale of Wardour (occupying the lower part of the group in the adjoining section); and being perhaps also represented in certain beds

of shelly limestone of considerable thickness, at Pounceford and Ashburnham in Sussex.



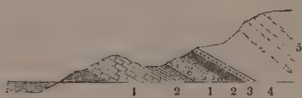
SECTION IN THE VALE OF WARDOUR.

The Purbeck strata, thus shown to be the base of the Wealden formation, may be divided into two parts, the lowest of them being a coarsely fissile limestone, locally called "slate," which has been used for roofing and other economical purposes. This bed, together with a slaty clay with which it is associated, is of considerable thickness, and is succeeded by finer compact limestones, abounding with bivalve shells of the fresh-water genus "Cyclas." These compact fossiliferous limestones again alternate with clay, and include a thick bed, called by the workmen "cinder," almost entirely composed of oyster shells. The limestones of this part of the series are quarried for building purposes, as many as fifty-five beds of useful stone being known; and the whole thickness of the upper member of the group amounts to about 125 feet. The beds at the top consist chiefly of the remains of an univalve shell (*Paludina*) cemented together by carbonate of lime and a large proportion of green matter; they have formerly been much worked, and are well known under the name of Purbeck marble.*

Along the coast of Dorsetshire to the west of Purbeck, the Purbeck series is frequently exhibited, although the strata are much disturbed from their horizontal position.

* The Purbeck marble was formerly used in the internal decoration of cathedrals, &c., the slender shafts of columns being sometimes made of it.

At one spot (Lulworth Cove), shown in the accompanying diagram, the dip is very considerable, and not far off on the same coast the beds are fairly set on end.



SECTION.—LULWORTH COVE.*

The passage from the Purbeck beds to the overlying Wealden deposit is well seen in several places on the coast of Dorsetshire, and may be observed either in the Isle of Purbeck itself (see section, p. 366,) or at Lulworth Cove, the locality just alluded to. In both these spots the Purbeck limestones are surmounted by a considerable thickness of sandy beds, to which the name "Hastings sand" has been given; and these constitute the middle member of the Wealden formation.

II. Hastings sand.—This group of beds, which forms by far the most important member of the Wealden group, not only in thickness and extent, but also in the fossil remains obtained from it, is composed of numerous strata of sand, sandstone, grit, and shale, all of fresh-water origin. These strata occupy the cliffs along the south-east coast of England, between Folkstone and Beachy Head, and again on the coast of Dorsetshire, where they are covered up by the Purbeck limestone. They are also found in the

* Cretaceous:
5. Upper chalk, with flints.
4. Lower chalk.
3. Upper green sand.
2. Gault.
1. Lower green sand.

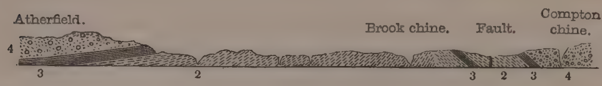
Weald . . :
2. Hastings sand.
1. Purbeck beds.

Isle of Wight, and in the counties of Kent and Sussex they occupy, with the Weald clay, nearly the whole space between the North and South Downs, being thus enclosed in an irregular triangle, the base of which extends from Hythe to Beachy Head, and whose apex is in the west of Sussex, a little to the east of Petersfield. Within this district the Hastings sands form the lowest strata in geological position, but are elevated into hills, known as the Crowborough and Tilgate Forest ranges. The Weald clay covers up the Hastings sand both on the north and south, and is itself soon hidden by the overlying beds of the lower members of the Cretaceous system.

The lower beds of the Hastings sand are well seen in the cliffs near Hastings, and consist of a friable sandstone (in which caverns are excavated) based on beds of shelly limestone, and grit, and alternating with shale and clay. These strata are overlaid by another series of sandy beds, containing a fine building stone, and, together with the former ones, they abound with organic remains, chiefly those of fresh-water molluscs.

The Tilgate beds may be considered to form a group occupying the upper place in the Hastings sand series; and they receive their name from having been formerly extensively quarried in Tilgate Forest near Horsham. They consist of several bands of bluish grey sandstone or rather calcareous grit, which are of no great thickness, and alternate with friable sandstones, some of them highly ferruginous, others of a white colour and without iron, and others again containing particles of lignite. The lower of these beds form a conglomerate, containing pebbles of quartz, which have apparently been transported from a great distance.

In the Isle of Wight the Hastings sand is well exhibited, and the way in which the beds appear, brought up by an anticlinal axis, will be understood from the annexed section across part of the south-eastern coast of the island,



SOUTH-EAST COAST OF THE ISLE OF WIGHT.*

between Compton Chine, and Atherfield. The same thing is repeated on the south-western coast. The predominant beds here consist of sands and gritstones like those of the Wealden district; and over these are found large concretional masses of grit, separated from the former by a sandy clay alternating with shale, and corresponding to the Tilgate stone, not only in mineral character but also in fossils. It is chiefly in the upper portion of the Hastings sand, and in the centre of the Wealden district that the numerous and interesting fossil remains of land reptiles of the Weald have been found.

III. Weald clay.—This uppermost member of the Wealden group, though rarely of greater breadth than five or six miles, may be distinctly traced, forming a zone of clay covering up the edges of the Hastings sand, and passing under the various beds of the cretaceous system. It is also visible on the coast of the Isle of Wight, forming a narrow band, encircling and almost insulating the Hastings sand.

The strata which form the base of this superjacent group consist of beds of sandstone and shelly limestone, with layers of argillaceous ironstone.† The limestone is

* In this section 2, 3, represent the middle and upper members of the Wealden group, and 4, the overlying bed of lower greensand (*Neocomien*).

† See diagram, p. 46.

called "Sussex marble," and is strikingly characteristic of the Weald clay in England, occurring in layers which vary from a few inches to more than a foot in thickness, and which are separated from each other by seams of clay, or coarse friable limestone.* It is almost entirely made up of fossil shells (*Paludina*), united by a calcareous cement into compact marble, and has been used, like the Purbeck marble, in the internal decoration of churches and cathedrals, and to make the small insulated shafts of pillars so common in Gothic Architecture.

The limestone, however, is not the only one of the upper Wealden strata which has been used for economical purposes, the argillaceous iron ore having been formerly worked on the borders of the once extensive forests of the Weald.

The clayey band from which the name Weald clay is derived, is in some respects the least remarkable portion of the formation, as it presents no character on the surface except being favourable to the growth of the oak, whence it was originally called by Dr. Mantell the Oak Tree Clay. It abounds with fossils, but they are for the most part badly preserved, and consist chiefly of fragments of fresh-water shells.

Besides the principal development of the Wealden formations in the counties of Kent and Sussex, and in the Isle of Wight, there are two or three valleys of elevation in the adjoining counties to the west, in which some of the strata are brought again to the surface. The Vale of Wardour, the Vale of Aylesbury, and the Valley of the Nidder, have all been described as exhibiting Wealden deposits, and the Purbeck beds in one of these (the Vale of Wardour) have already been alluded to. In these cases there is

* Mantell's Geol. of S. E. of Engl. p. 184.

said to be no trace of the dirt-bed, but the upper layers of the Portland stone have been much disturbed, and are succeeded by a few inches of black earthy clay, and beds of fossiliferous limestone, containing minute freshwater crustaceans, freshwater shells, and fragments of fossil wood.*

The most careful research has hitherto failed in discovering any deposit similar to the Weald in other parts of England. In the Isle of Skye, however, Professor Sedgwick and Mr. Murchison observed certain flattened masses of limestone containing shells, which on careful examination were found to belong to Wealden species. In one or two places, again, on the coast of France, opposite the principal development of the Weald in England, such as in the Bas Boulonnois, and in the Pays de Bray, there have also been discovered similar beds of freshwater origin of the same period. Both of these are exposed in valleys of elevation in the chalk; and both seem to show, from the faintness with which the Wealden beds are indicated, that we have arrived at the limit of the formation, by the actual thinning out and final disappearance of the beds.

In the north-west of Germany there is found a series of strata as much as 800 feet in thickness, overlying the ordinary Oolitic strata, and consisting of two hundred feet of sandstone, interposed between thick masses of black shale, the whole of which have been referred by M. Von Roemer to the period of the Wealden formation. The evidence upon which the identification rests may be considered, perhaps, insufficient so far as regards the underlying marls and sandstone; but in certain marls which rest on the sandstone there have been found freshwater shells and crustaceans (Cypris), which certainly appear to render it probable that

* Geol. Proc. vol. iii. p. 780.

the marls in question represent the Weald clay. The fossil remains of Crocodilian reptiles have been found at Bückeburg in this formation.*

The consideration of marine beds contemporaneous with the Wealden is necessarily a subject involved in considerable difficulty, because there can be no certain means of comparison and identification. It is obvious that a series of beds, whose total thickness is not much less than a thousand feet, must have taken a long time for its accumulation; and that, during that time, the waters of the sea must have been depositing marine remains, while the rivers were accumulating those myriads of shells which are found in the Weald clay, and Hastings sand; but we should not forget that the very magnitude of the freshwater deposit we are considering, and its extent, is sufficient proof that there existed, at no great distance from the Wealden deposits, extensive tracts of land.

At all events there is at present no sufficient proof that the lower beds of the Cretaceous system, extensively developed in some parts of the Continent, necessarily represent an intermediate link between the Oolites and our lower green sand; and in the absence of proof from fossils, we are not justified in supposing that these beds, called by the French "Neocomien," truly represent anything more than the lower part of the Cretaceous group, the fossils of which, as exhibited in our own country, they undoubtedly contain.

It is, perhaps, more probable, that the marine formations of this period will be found in some other and distant localities; and, perhaps, from the south of India, where the existence of a remarkable series of fossiliferous

* Von Roemer's Versteinerungen des nord-deutschen Oolith-Gebirges. Hanover, 1836. p. 14.

rocks has been lately determined, we may venture to anticipate some results not without considerable interest as bearing on this point. At any rate, the comparisons and investigations that have been hitherto made, with regard to such of the fossils of these districts as have reached England, are well worthy of being the groundwork of most careful examination on the spot.*

* I allude to the beds of Trichinopoly and Verdichellum, which will be more particularly described in speaking of the foreign cretaceous rocks. The investigations of Prof. Edward Forbes with regard to the fossils from these beds are of very great interest, inasmuch as they indicate the possibility of there being a true representative of the Wealden group in that part of Asia.

CHAPTER XXIX.

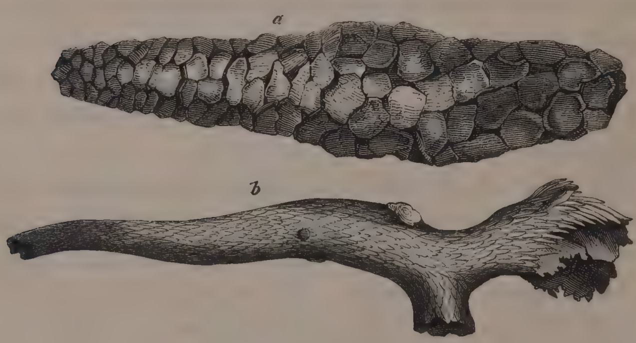
THE FOSSILS OF THE WEALDEN FORMATION.

The fossil remains found in the strata of the Weald are referrible, as I have already mentioned, to land animals or vegetables, or to species inhabiting the fresh water of rivers, lakes, or estuaries. The number of species thus known is not large, but the fossils are abundant to an extent rarely observed in other formations, and the interest attaching to them is the greater, as they are capable of being compared with many analogous species now dwelling in similar localities, and under similar circumstances.

But although the number of fossils to be obtained from the various Wealden strata is very considerable, the condition in which they are found is rarely such as to afford much valuable information. Owing probably to the nature of the deposit, which consists chiefly of coarse sand, the smaller and more delicate bones of land animals have been crushed and destroyed, and, in some cases, even the trunks of large trees have so far suffered from the violence to which they have been subjected, that we are hardly able to judge of their actual form and structure. It is chiefly also in the marly beds, occasionally alternating with the sands, that we find shells sufficiently well preserved to enable the Conchologist to identify them; but, in spite of

these difficulties, the active researches of collectors have not failed to discover many interesting fragments which have formed exceedingly valuable additions to Palæontological knowledge.

Among the vegetable remains of this, the newest part of the middle Secondary period, we find a few additions to the flora of the Oolites, although the general character of the vegetation is the same. Occasionally the marks of fucoids, but more frequently the fronds of ferns or Cycadeæ, and the silicified trunks of large coniferous trees, denote this peculiar character; and only two genera (*Clathraria* and *Endogenites*) seem to require special notice. But even with regard to these, very little is known, nor have their true analogies been satisfactorily made out.



CLATHRARIA LYELLI. MANTELL.

Dr. Mantell describes the CLATHRARIA as having possessed a thick epidermis or false bark, formed by the union of the bases of the leaves, and covered by distinct scales, these latter being either the attachments of the footstalks of the leaves, or the bases of the leaves themselves. The dimen-

sions of the ordinary specimens prove that the tree attained considerable size, but the interior is rarely more than a sandstone cast, the outside showing the scars at the bases of the leaves. The condition of the inside is probably owing to the succulent nature of the plant and its monocotyledonous analogies, and it probably belonged to the family "Cycadeæ" already described.

The fossils to which the name Endogenites has been applied are manifestly of vegetable origin and monocotyledonous; but it is not yet known certainly to what family of plants they really belonged. Specimens are generally found in great numbers together:—they are elongated, elliptical bodies, flattened and tapering at both extremities; but the original form was, no doubt, cylindrical, and indeed that shape is retained in one specimen (in the British Museum), and most of the others are compressed in various directions and irregularly.

These singular fossils are sometimes of very considerable size, measuring as much as eight feet along the major axis of the ellipse: they are covered with a dark carbonaceous matter, which may be removed by washing, and they generally consist of two distinct portions, a stony nucleus, and a crust or core of lignite, varying in thickness, and often extending considerably beyond the extremity of the nucleus. The external surface of most of the specimens is scored with grooves and deep longitudinal furrows, and a transverse section examined under the microscope exhibits numerous pores formed by the division of vessels, and proving the monocotyledonous structure of the original.

Besides these vegetable remains, there have been found occasionally, in the grits of Tilgate forest, fruits or ker-

nels resembling those of certain palms, and supposed by M. Brongniart to have been the seed-vessels of the Clathraria. These accompany a number of ferns, which are particularly interesting, as being the last specimens met with of many of those genera which were abundant during the Oolitic period.

The fossil Invertebrata of the Weald are few in the number of species to which they are referred, and also wanting in interest, as they differ but little from those peopling the rivers and estuaries of the present day. The most plentiful are the shells of a small crustacean of the genus Cypris, which are incredibly abundant throughout the Wealden strata. The animal was enclosed within two valves of oblong shape, and was not more than one-tenth of an inch long, the substance of the shell being coriaceous, but brittle, and very thin. Several species have been determined by Dr. Fitton.

But besides these there have been found in the Wealden deposits of the Vale of Wardour, and also in the Vale of Aylesbury, numerous remains of a singular little animal, whose external appearance seems to have resembled that of the common woodlouse, and which has been referred to a new genus of *Isopoda*, a group of crustaceans nearly allied to that which includes the Trilobites. The body of these crustaceans is very flat, and is composed of a series of segments terminated posteriorly by a sort of rounded buckler. Traces of the feet, and marks of the impressions of the antennæ, have been distinguished in some specimens, and in one or two instances even the lenses of the eye are preserved, but the head is generally much injured.*

ARCHÆONISCUS BRODEI. M. EDW.

* Annals of Nat. Hist. vol. xiii. p. 110.

These remains occur in clusters in a bed which contains also fragments of various insects and other fossils, and they vary in size, many specimens being almost microscopic, while others measure an inch in length, and are half an inch broad.

The insects of the Weald, although very minute, are also of great interest to the Palæontologist. They consist chiefly of Coleoptera or beetles, but include also many species referred to the orders Homoptera and Tricoptera, and some species of Dipterus, which present distinctly the wings and legs, and the striæ of the abdomen. By far the most abundant species belong to those families of insects which live on plants, or hover over the surface of streams.*

The remains of the shells of Mollusca are, in some localities, exceedingly abundant; but the number of genera and species is small. The shells are exclusively those of animals who once inhabited fresh water, and they are referred chiefly to a few extinct species of Cyclas, Melanopsis, and Paludina. Entire beds are often composed of the broken remains of a single species of each of these genera; but they offer no peculiarities of structure which render it necessary to dwell longer on the subject in this place.

The remains of fish found in the Weald are chiefly confined to imperfect fragments, but have been referred to as many as thirteen species, of which the greater number are supposed to have inhabited shallow water, and to have

* The fact of the existence of these insect and crustacean remains in the Weald was first ascertained by the Rev. P. B. Brodie. Mr. Brodie has announced his intention of publishing shortly (by subscription) an account of the numerous insects he has found in the Wealden beds and the Lias: the value of a monograph of this kind must be sufficiently evident, and deserves every encouragement from naturalists. See Proceed. Geol. Soc. vol. iii. pp. 135, 781.

prowled about in the mud in search of food. The scales and teeth of one of these (*Lepidotus*, Ag.) are sufficiently common; the former are large, of dark brown colour, and rhomboidal shape, and with a highly polished enamelled surface: the latter are hemispherical, intended rather for crushing than biting, and, being disposed in rows on a bony palate, are admirably fitted for this purpose. Remains of the genus *Hybodus*, as well of teeth as of defensive fins, are also common, and, together with the others, indicate most decidedly the analogies possessed by the Wealden strata with the Oolites rather than the beds of the Cretaceous system.

But it is the Reptilian remains that are most interesting and remarkable among the Wealden fossils, as many as one-sixth of the whole number of extinct reptilian species yet known, being found in this formation. Five genera also are peculiar to it, and of each of these five I must now say a few words. The *Suchosaurus* and *Goniopholis* are referred by Professor Owen to his CROCODILIAN order of reptiles. The *Iguanodon* and *Hylæosaurus* to the DINOSAURIA, while *Tretosternon*, together with some other turtles, belongs to the order CHELONIA. The remains of the *Poikilopleuron* and *Streptospondylus* are also occasionally found, and the *Plesiosaurus*, the *Megalosaurus*, and the *Cetiosaurus* make up the singular list of reptilian inhabitants of the earth and sea, at the close of the Oolitic period.

The Crocodilians of the Weald are remarkable for the same singular structure of the vertebræ which distinguishes the Oolitic from the recent species, each of the two genera peculiar to the formation having bi-concave vertebræ, indicating distinctly the aquatic habits of the animal. Judging from the structure of the teeth (which somewhat

resemble those of the Megalosaurus,) the *Suchosaurus* was probably a long snouted crocodile, not unlike the Gavial or piscivorous crocodile of the Ganges; but with regard to the *Goniopholis*, Professor Owen remarks, that the teeth of this genus are as remarkable for their thick rounded obtuse crown as those of the former for their slender, compressed, acute, and trenchant character; and the animal must have approximated to the broad and comparatively short snouted crocodiles, although the careful examination of a large collection of bones referred to the genus has shown that there were, notwithstanding, very considerable differences.*

One of the first points which attracts the attention of the Comparative Anatomist in studying this latter genus (*Goniopholis*), a specimen of which is now in the British Museum, is the number and relative size of its large bony scales or dermal plates, which are more perfectly and powerfully arranged than in any other known reptile, recent or extinct. In this point the Goniopholis appears to approach the structure of the Teleosaurus, considered by Cuvier as "l'espèce le mieux cuirassé de tout le genre;" but in other respects, and more especially in its bi-concave vertebræ, and several modifications of the pelvis, its habits appear to have been more decidedly marine than those of any other Crocodilian, and rather resembling those of the Enaliosaurian tribe. The jaws must have been very powerful, much more so, at least, than those of the slender toothed Crocodilians; but their real length and form there are not at present sufficient means to determine.†

* Report on British Fossil Reptiles, &c., by Prof. Owen, p. 69.

† Loc. cit. p. 72.

Of the order Dinosauria the remains of the carnivorous *Megalosaurus* have been found occasionally in the Wealden strata, and they are there accompanied by various fragments referred to other genera, perhaps equally remarkable, which have been named respectively *Hylæosaurus* and *Iguanodon*.

The Hylæosaurus (or Lizard of the Weald) appears to have been a land Saurian of very large proportions, (probably as much as fifteen feet in length,) and covered with scales or dermal plates of moderate size and elliptical shape, which seem to have irregularly studded the skin. A knowledge of the former existence of this animal was first obtained from a specimen obtained by Dr. Mantell from the Tilgate beds, containing several important parts of the skeleton in almost natural juxta-position. These parts consist of a fragment of the skull, several vertebræ, portions of the fore extremities, several ribs, a considerable number of dermal plates or scales, and a series of bones, supposed by the discoverer to have formed a kind of fringe or crest running along the middle of the back of the animal.

Of these bones the vertebræ seem to indicate distinctly the Dinosaurian type and the land habits of the Reptile; the fragment of the skull approximates the genus to the Crocodiles; and the ribs also, in their strong and double articulation, seem to point to similar analogies; but the bones of the extremities are very remarkable; and, as well as the supposed dorsal fringe, require a description somewhat more in detail.

The scapula or blade bone of the Hylæosaurus is long and narrow compared with that of recent Monitors, and adheres to the Crocodilian type in the shape of the blade;

but it is provided with a strong ridge, obtuse, and separated by a deep and wide groove from the surfaces at which the humerus and coracoids are attached; and this process would appear to exist in other Dinosaurs, indicating a remarkable approach to the Mammalian type of structure.

The coracoids are simple in form, and resemble those of the chameleon, deviating in their great breadth from the Crocodilian type. The sacrum appears to consist of four or five vertebræ firmly anchylosed, as in the other Dinosaurs.

With regard to the so-called dermal spines, they consist of a series of flat bones, the first seventeen inches long and five inches broad at the base, the others decreasing rapidly in length, but slightly increasing in breadth. It is suggested by Professor Owen, that they may have been abdominal ribs, instead of a dermal fringe; but it is a matter that has yet to be decided by the discovery of other more distinctive fragments of this interesting genus.

The companion of the Hylæosaurus in the ancient swamps and forests of the Wealden district is the gigantic herbivorous animal which has been called Iguanodon. This name was suggested from a comparison of some specimens of the teeth with those of a recent reptile, the Iguana, and the observations of Cuvier, by whose assistance the nature of the animal was first determined, are well worth recording.

"These teeth are unknown to me," he writes; "they do not belong to a carnivorous animal, and yet they must, from various appearances, be Reptilian; for although, at first sight, one might fancy they had belonged to a fish,

yet their internal structure is completely different. May we not have here a new animal—a herbivorous reptile?—and as among living terrestrial animals the herbivora are the largest, why should not the same have been the case among the reptiles in former times, so that, when they were almost the only inhabitants of the land, the largest amongst them should be vegetable feeders? Time will prove or disprove the accuracy of this idea, for some portions of the skeleton and fragments of the jaw must ultimately be found."* Other fragments, indeed, were afterwards found, and fully bore out the view taken by the French Anatomist; and although, as might be expected, there are many important differences between the structure of the monstrous Iguanodon and that of any existing Lacertian animals, the above suggestions of Cuvier are in the main accurately descriptive of the new genus.

As it was from the structure of the dental apparatus that the name Iguanodon was derived, (the recent Iguana having been found by Dr. Mantell to possess teeth greatly resembling in form and structure those of the hitherto unknown genus,) this important part of the animal economy may be first considered with reference to the habits of the species, and the group of Saurians to which it must be referred.

In the first place the teeth of the Iguanodon, though resembling closely those of the Iguana in external appearance, differ essentially in internal structure by a peculiarity in which the Iguanodon differs also from every other known Reptile. The teeth, too, differ in the nature of their attachment to the jaw, for instead of merely adhering to the inner side, they were placed in separate sockets as in the Crocodile, and thus obtained a sup-

* Notice on the Iguanodon by Dr. Mantell, Phil. Trans. 1825.

port which the greatly worn condition of several specimens shows to have been quite necessary.

TOOTH OF IGUANODON.

The contrivances for rendering the teeth of the Iguanodon efficient instruments in cropping and masticating tough vegetable food, (such as the Clathraria and other Cycadeæ which seem to have chiefly abounded at that time,) are extremely interesting, and have been admirably stated by Dr. Buckland.*

The base of the tooth is elongated and narrowed like that of the Iguana, but the crown is expanded, and is convex on the inner side, its sloping sides being jagged and rough, and the external surface coated by a layer of enamel. As the tooth became worn the fang and the crown were both gradually diminished, but in consequence of two provisions, namely, the sharp serrated edge extending from the point to the broadest portion of the body of the tooth, and the plate of thin enamel maintaining a cutting edge so long as the tooth lasted, there remained always the power of nipping and tearing the toughest vegetable fibre; until, when the crown was worn away below the base of the enamel, the tooth exchanged the functions of an incisor for that of a grinder, and was prepared to give the final compression, or comminution, to the coarsely divided vegetable matter.†

* Bridgwater Treatise, vol. i. p. 246. Owen's Report, 1841, p. 122.

† "The perpetual edge resulted from the enamel being placed only on the front of the tooth, like that on the incisor of the Beaver, Rat, and other Rodents. As the softer material of the tooth itself must have worn away more readily than this enamel, and most readily at the part remotest from it, an oblique section of the crown was thus perpetually maintained with a sharp cutting edge in front like that of the nippers."—Buckland, Br. T. p. 247, note.

The vertebræ of the Iguanodon have their bodies terminated by flat or slightly concave articular surfaces, but unfortunately there are, at present, no fragments that can be referred to the region of the neck, which is the part most characteristic, and most to be depended on in determining the analogies with other Saurians. The dorsal vertebræ approach the type of Crocodilian structure rather than that of the Iguana, and in this resemble the corresponding bones of other Dinosaurs. The sacrum, also, consisting as in the Megalosaurus of five vertebræ anchylosed together so as to form a continuous ridge of bone, exhibits strikingly the same peculiar character; and this group of vertebræ, measuring in one specimen seventeen inches in length, and (including the iliac bones also anchylosed to the mass,) thirteen inches in breadth, exhibits in a most striking manner the gigantic proportions of the animal. "The proportion of the spine thus grasped as it were by the bones of the pelvis, which transmit the weight of the body upon the thigh bones, corresponded no doubt to the mass which was to be sustained and moved, and the size and structure of this part indicate, with those of the femur and tibia, the adaptation of the present great herbivorous Saurian for terrestrial life." *

The remaining vertebræ, those of the tail, indicate that this part of the animal was shorter in proportion than in the Crocodile, and very dissimilar, in this respect, to the Iguana; they prove, also, that the tail must have been flattened laterally, and was of great breadth in the vertical direction, at least near its base.

The ribs are exceedingly large and broad. They were attached to the vertebræ by a double articulation, and bend with a deep oblique curve for about one-fifth of

* Owen's Report, 1841, p. 130.

their length. They are afterwards continued in a nearly straight line, and the extremity is slightly expanded and truncated, as if for the attachment of bony sternal ribs.

The bones of the extremities of this strange animal are not less remarkable than the other parts of the skeleton, but the specimens of them at present discovered are fragmentary and not very satisfactory. The femur, or humerus, appears to have been at least three feet in length, and the tibia nearly as much; but the humerus is so nearly like the femur in reptiles generally, and probably in the Dinosaurs more especially, that it has not been possible to determine the nature of the difference that exists between them. With regard to these bones, they depart entirely from the type of Iguana, both in proportions, and even in important anatomical details, and they seem to have supported the weight of the body in a manner much more nearly resembling that in the Pachydermal Mammalia than in any reptile, the body being elevated above the ground to a considerable height.

The bones of the foot, several of which have been discovered, show that here also the structure of the Iguanodon was very remarkable. The metacarpals (the bones corresponding to those of the palm of the hand,) measure two feet six inches in length, and the ungueal phalanx (the last joint of the toe, to which the nail is attached,) is five inches and a half long. Whatever may have been the proportion of the intermediate bones the dimensions of the foot must, therefore, have been extremely gigantic.

With regard to the actual length of the animal, however, it appears probable that the first calculations made were greatly exaggerated. By calculating the number and dimensions of the vertebræ,—the only safe method of cal-

culation,—Professor Owen has given the following as the probable size :—

	Feet.
Length of head, say, ...	3
„ trunk with sacrum . .	12
„ tail	13
Total length of *Iguanodon** .	28

But this view of its length gives but an imperfect idea of the real nature of the extraordinary monster whose remains we have been considering, for it is rather in its unusually massive proportions and anatomical structure, than in its length, that it really differs so widely from any known genus of Reptilian animals.

It is this Iguanodon which, with the Megalosaurus and the Hylæosaurus, " form a natural order combining a complicated dentition, (the teeth being implanted in sockets,) with limbs proportionably large and strong, having well developed marrow-bones, and sustaining the weight of the trunk by a long and complicated sacrum firmly cemented into one great ridge of bone. These modifications, undeniably the most perfect of the reptilian type, are found in animals which attained the greatest bulk, and must have played the most conspicuous parts, in their respective characters as devourers of animals and feeders upon vegetables, that this earth has ever witnessed in oviparous and cold-blooded creatures."†

And lastly, these animals so large, and so strange, were by no means rare during the period of the existence of their species upon the earth. Dr. Mantell calculates that not less than seventy individuals of the Iguanodon of all ages have come under his notice, and doubtless many more have been destroyed by the workmen; and all these

* Report, &c., p. 144.

† Owen's Report, &c., p. 200.

have been found in the few quarries of Tilgate grit, opened of late years for economical purposes.

It is difficult to conceive the abundance of the animals by such indications of their remains, for there is no reason to suppose that they were confined in their locality to a particular spot; nor even to the extensive tract which is covered by the Wealden deposits in the south-east of England, or to any particular part of the thousand feet of vertical thickness of which these strata consist.*

Besides the Saurians of the Dinosaurian order, there are also found in the Wealden deposits, and more particularly in the Purbeck limestone, the remains of a species of fresh-water turtle, which has been described by Professor Owen under the generic designation of *Tretosternon.* The dimensions of the carapace, or shell, in one specimen are about 17 inches by 13½, and the genus is interesting in its relation to the other genera of Chelonian reptiles, and as forming a transition to some more ancient forms. Its shape is broad and extremely flattened;—the external surface of the carapace is covered with minute irregular impressions, and it is probable that the marginal plates were either wanting or rudimentary. In addition to the Tretosternon, several other Chelonian animals have been preserved in the Purbeck limestone and the Tilgate beds, and amongst them more than one species of true marine turtles (*Chelone*).

Fragments of bones, referred to an extinct species of

* At the same time it must be borne in mind that, for reasons it is not easy to guess at, there do seem to be particular spots where the remains of certain species of animals are more than usually abundant. With regard to gregarious animals among the invertebrata, this is not so extraordinary; but that particular parts of a sea or river should be selected as a kind of hospital or dying-place by the larger vertebrata is certainly not a little remarkable. Something of the kind, however, is apparent in the Lias and the Old red sandstone, as well as in more recent formations.

wading birds, have been from time to time discovered in the Wealden beds; but they are too few and imperfect to do more than indicate the fact of the existence of animals of this class at the close of the Oolitic period. It cannot excite astonishment that such extremely delicate bones as those of birds should but rarely occur in a fossil state; and we are not at all in a condition to assume that, because their remains are not preserved, these animals did not exist during the earlier periods of the earth's history. The marks of footsteps, supposed to have been left by some species of large size, have already been described as occurring in the New red sandstone, and the occurrence of these few fragments in the Weald adds to the probability of the race having existed long before.

No remains of any kind which can be referred to Mammalia have yet been discovered in the Wealden beds.

CHAPTER XXX.

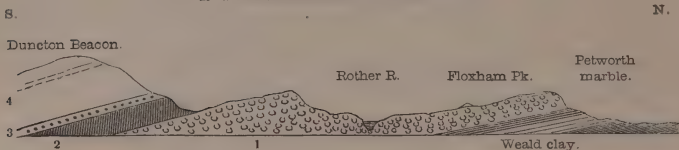
THE CRETACEOUS FORMATIONS OF THE BRITISH ISLANDS.

The cretaceous system of formations has received its name from the abundance of white chalk (*creta*) found in the upper part of a somewhat extensive group of strata, which rest upon the fresh-water deposits of the Weald, and are unquestionably of marine origin. This group is often found lying conformably either on the Weald clay, or, in the absence of Wealden deposits, on the upper beds of the Oolites; but the fossils of the latter differ more completely from those of the chalk than do the fossils of the Portland Stone and Kimmeridge Clay from those of the Lias.

Not only in England, but also in a considerable portion of Western Europe, the subdivisions of the whole group will be found to correspond very exactly with the subjoined table. In speaking of the Foreign Geology of this period, I shall, indeed, have occasion to mention several peculiarities of appearance known to occur in various mountain districts; but these are comparatively few and unimportant, when compared with the much larger districts in which the order of succession is regular and undisturbed.

CRETACEOUS GROUP	II. CHALK FORMATION . .	6. Maestricht beds. 5. Chalk with flints. 4. Chalk without flints and chalk marl.
	I. GREEN-SAND FORMATION	3. Upper green-sand. 2. Gault. 1. Lower green-sand (*Neocomien.*)

I. THE GREEN-SAND FORMATION.



GREEN-SAND FORMATION IN WESTERN SUSSEX.*

The Green-sand formation, consisting of two arenaceous beds, with a parting of clay called gault, has received its name from the prevalence of small green particles of silicate of iron distributed through the sand. It is very distinctly marked as a group of beds underlying the chalk, and is traceable throughout England, although greatly altered in character towards the north, where the lower sand is gradually lost sight of.

THE LOWER GREEN-SAND.—The passage from the Weald clay to the Lower green-sand is usually somewhat abrupt; an escarpment of stone containing the well known *Kentish rag*, and other hard concretions covering up the clay, and in consequence of an entire difference in mineral character as well as fossil contents, generally contrasting very strongly with the underlying beds. The outcrop of the Weald clay is, however, not unfrequently marked by the presence of a line of springs.

The lower part of the Lower green-sand contains on the

* The numbers refer to the table given above.

whole much more calcareous matter than the upper beds, and has even been worked occasionally for lime-burning. It abounds in some places with the numerous small green grains of silicate of iron, whence the name of the whole group has been derived (such particles not often occurring in the beds of any other formation).

Above these calcareous and concretionary beds, and forming a middle portion of the Lower green-sand, there is generally found a dark coloured sand, containing fragments of silicified wood, and then another sandy bed of variable but considerable thickness, remarkable for its red or rusty yellow colour, which it owes to oxide of iron.

Lastly, the uppermost member is chiefly composed of grey and yellowish sand, containing numerous cherty concretions, which often enclose grains of greenish sandy matter, indicating the presence of the silicate of iron already alluded to. These three subdivisions are traceable throughout the south-east of England, and are marked in the section given in the adjoining page; they probably obtain also in some parts of the interior of the country far removed from the Wealden district.

In the Isle of Wight they have also been determined, and they are generally marked so distinctly by the physical features of the country, that the Geologist has only to follow out the indications thus afforded him, to discover the points at which this group is exposed.

One of the best sections in the island may be seen on the south coast between Black gang chine and Atherfield point, where the junction of the lowest beds of green-sand with the Weald clay is well shown.* The stratum near this junction consists of a hard stone about two feet thick, abounding with fossils, many of them peculiar to this por-

* See diagram, p. 426.

tion of the formation, but many also which are common to the whole of the lower green-sand. At Atherfield the actual junction consists of a bed of clay resting conformably upon the Weald clay, but not passing into it, and remarkable for possessing in great abundance the fossil remains of fishes.

It is worthy of notice, that in this part of England where the lower members of the Cretaceous group are so well developed, the lowest or Neocomien beds are chiefly composed of brownish clay, in some places very fossiliferous (abounding in crustaceans in the upper part) and occasionally passing into a kind of Fuller's earth. The transition thus made, the overlying or middle portion of the green-sand is arenaceous, and containszones of a kind of oyster (*Gryphæa sinuata*) alternating with bands of nodules, in which occur the remains of large Cephalopoda (*Crioceratites*, &c.). The upper beds upon which the Gault rests are more or less sandy, with several lines of hard rock. They are highly ferruginous, and for the most part free from organic remains.

The green-sand and the other cretaceous deposits are admirably exhibited at the foot of the North and South Downs of Kent and Sussex, between which the Wealden district is contained, and the complete sequence must be sought for there, although the development of the formation is by no means confined to that locality. To the west of the Wealden districts, and commencing on the coast near Weymouth, the beds of the green-sand formation may be traced almost continuously, as far as the northern extremity of the county of Norfolk, occupying a more or less important position between the Chalk and the Oolites; while almost throughout the whole distance the subdivisions are preserved, and the lower green-

sand can be detected. Quite in the south-west the gault is wanting, and numerous important outliers there occur, without any satisfactory means of determining to what part of the formation they must be referred. Further north, and towards Bedfordshire and Cambridgeshire, the distinction is, however, clear; and the lower part of the formation is chiefly a ferruginous sand of a deep red colour, well seen in the roads at Gamlingay, Potton, &c. This highly ferruginous character may also be remarked in the beds of the same date in Norfolk, although all indications of the subdivision into three groups has there entirely ceased. The thickness of the Lower green-sand varies considerably, but it seems rarely to exceed 300 feet, and is often much less.

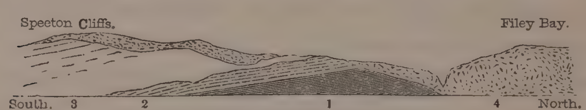
The GAULT:—immediately overlying the Lower green-sand—is rarely absent, and may, perhaps, be considered as the most persistent of all the beds of the Cretaceous group, scarcely ever changing its peculiarities of mineral composition or fossil remains. At Folkstone, where it is seen in perfection, it rises gradually towards the west of the town, and forms a cliff about 120 feet thick, resting distinctly on the lower green-sand, the section being well exposed, and the stratum extremely fossiliferous.

Gault is a provincial term, used originally in the middle of England, to designate the brick clay, which there belongs to that part of the Cretaceous system we are now considering. It is a stiff clay of a blue colour, and the inferior portion of it abounds with iron pyrites, while the upper part contains green particles of silicate of iron. Various nodules and concretions are found throughout, which are sometimes fossiliferous, but more frequently obscure, and of doubtful origin.

The Gault of the Isle of Wight conforms less accurately

than usual to the ordinary condition and appearance of the bed elsewhere. Its thickness is not so great, the clay is harsher and more sandy, and seems to contain but few fossils, and according to Dr. Fitton, the bed represents the upper part of the Gault, the lower part being absent.* In the Vale of Wardour the strata below the chalk, as far as the Purbeck series, are exposed in a valley of elevation, and the position of the Gault with respect to the beds associated with it will be understood by referring to the diagram, p. 423.† It there contains the characteristic fossils, and attains a thickness of about seventy-five feet.

From this point towards the north-east the gault is found whenever its proper place among the strata is reached, and it gradually increases in thickness, as far as the vicinity of Cambridge, after which it diminishes, until in West Norfolk it is not more than fifteen feet



CRETACEOUS SERIES—YORKSHIRE COAST.‡

thick. Lastly, a bed, called the Speeton Clay, comes out below the chalk on the coast of Yorkshire, and has been supposed to belong to this part of the Cretaceous group. It contains numerous fossils identical with those of the Gault as exhibited in the South of England.

* Trans. Geol. Soc. of London, 2d Ser. vol. iv. p. 184.

† In this section the bed marked (3) represents the gault.

‡ 4. Gravel covering up the chalk and other beds, and forming the cliffs to the north.
3. Chalk.
2. Speeton clay.
1. Kimmeridge clay.

The Upper Green-sand is not extensively shown in the cliffs of the South-east of England, but there is no doubt of its actual presence. It is chiefly in the interior of the country, and in the Isle of Wight, that it attains its greatest thickness, and most characteristic appearance. Between Godstone and Reigate, in Surrey, it begins to assume a decided character, and is there quarried for a particular kind of sandstone, called "fire-stone," which is valuable for lining fire-places and furnaces. Still further to the west, and near Petersfield, this part of the Cretaceous series becomes much more prominent, and runs out like a terrace beyond the foot of the chalk escarpment. Here also it passes insensibly into the lower chalk, but the whole of the terraces (which are at least two miles broad) are exclusively composed of this bed, locally called the "Malm-rock."

Something of a similar step-like appearance may also be observed in the Isle of Wight, where several admirable sections of it occur. One of the best of these is at the picturesque spot called Black Gang Chine, where the bed obtains a thickness of about 100 feet, the lower part being sandy, with spongiform masses, and the upper part containing abundance of chert, or hard siliceous rock —the Malm Rock of Western Sussex.

Proceeding northwards to the Vale of Wardour, (section p. 423,) the upper green-sand is still found to be well represented, the whole series of beds of which it is composed rising abruptly on the north side of the valley, and forming a narrow ridge of unequal height. The thickness here is as much as fifty or sixty feet, and the upper beds contain chert. In North Wiltshire the formation still occupies a slightly prominent step below the foot of the chalk, but towards the north-east it becomes less and less

important, until, in Bedfordshire, it is not more than seven feet thick, although it still retains its cherty character. In Cambridgeshire even this peculiarity is gone, but there is still about eighteen inches of a soft sandy mass, (rarely containing green particles,) separating the Gault from the lower chalk. The bed, however, though thus debased in its character, is remarkably persistent throughout; and further north it again contains chert and firestone, and is finally observed developed in its characteristic form on the Norfolk coast. It appears to be just possible, from the evidence of fossils, that the grey sandy chalk containing hard masses, which is found above the Speeton clay, on the Yorkshire coast, may also be the representative of this uppermost member of the Green-sand series.

Before concluding this account of the Green-sand formation some notice must be taken of a remarkable outlier, forming the Blackdown Hills in the county of Devonshire. These hills are capped by about 100 feet of sandy strata, representing the lower part of the Cretaceous system, and consist of layers of cherty concretions, alternating with loose sand. Four of the layers are worked for whetstones, the mines or pits being driven almost horizontally into the hill to a considerable distance, and the masses of which the whetstones are made varying from six to eighteen inches in diameter. The looser stone is employed for building.

From these workings numerous organic remains have been obtained, often in fine preservation, and converted into chalcedony. Upwards of a hundred and fifty species have thus been determined, of which ninety are not known to occur elsewhere in England, and the deposit must, probably, have taken place under circumstances somewhat different from those of the rest of the formation.

II. The Chalk Formation.

The Chalk is in some respects one of the most remarkable of all geological formations, the condition of the carbonate of lime, of which it is almost entirely composed, being altogether anomalous, while the layers of silex—the chalk flints—met with in the upper part, are equally puzzling to the Geologist, the Chemist, and the Zoologist.*

FOSSIL SHELLS FROM THE CHALK.

a. Inoceramus sulcatus. Park.
b. Ostrea canaliculata. Sow.
c. Terebratula plicatilis. Sow.

Although subdivisions of the whole mass have been attempted, they can hardly be considered other than extremely local; and it will be, perhaps, the most interesting and instructive method to consider the formation, at first, without reference to these details.

The range of the chalk through England is exceedingly

* I have thought it unnecessary to describe at any length the mineral character or general appearance of a rock so universally known as the chalk. It may, however, be worth while to mention that it is a nearly pure carbonate of lime, with a very small portion of water, its specific gravity being 2·3, and its composition, when quite pure,

Lime	56·50
Carbonic acid . .	43·00
Water	0·50
	100·00

well marked by a succession of rounded elevations, seen in perfection in the North and South Downs of Surrey and Sussex, and continued with a very similar appearance through the country as far as Flamborough Head, on the coast of Yorkshire. Commencing at Dover on the north, and Beachy Head on the south, of the great opening filled up by the Wealden deposits, the North and South Downs are continued westwards till they meet in the east of Hampshire, where they join another branch of similar downs, commencing with the cliffs between Weymouth and the Isle of Purbeck. The area thus occupied by the junction of the three chalk ranges includes all the north of Hampshire, and most of the south of Wiltshire. Its longest diameter, from east to west, is more than fifty miles, and its shortest, from north to south, about twenty.

From this great centre, the Marlborough Downs, the Whitehorse Hills, and the Ilsey Downs, conduct the chalk into Oxfordshire, where it is broken through by the valley of the Thames, but, crossing the valley, it is continued towards the north-east, by a succession of downs, through Buckinghamshire, Bedfordshire, and Cambridgeshire, into Norfolk. North of Thetford it occupies a low tract, but rises again towards Norwich, and is continued to the coast, forming the lofty cliffs between Cromer and Hunstanton. The Wash here again breaks the continuity of the stratum, but it reappears on the opposite coast, and then forms the Wolds of Lincolnshire, and, although intersected by the Humber, is continued across the river, constituting the Wolds of Yorkshire. It terminates near Flamborough Head, at Speeton, about six miles to the north of that promontory.

The chalk which has been described as originating the chain in the south, and which is seen in the Isle of

Purbeck, is continued also eastwards, and reappears in the Isle of Wight, forming a similar chain of downs. The vertical position of the beds in this island is the cause of numerous picturesque and highly interesting appearances, which are valuable evidences of the nature of disturbances, and the effects of subterranean force.

The general character of the districts occupied by the chalk is that of a perpetually undulating surface, the hills having a smooth rounded outline, with deep indentations on their sides, and with an escarpment, more or less precipitous, on the one side, but gently declining and lost under the overlying strata on the other. The chalk, also, more than almost any other bed, is broken by valleys transverse to its strike, and this is especially the case in the north and south downs.

The thickness of the whole formation may be considered to amount to about 1000 feet. The dip is generally small, but subject to great variation in the southern counties and the Isle of Wight. The loftiest height in England occupied by the chalk is said to be the Inkpen Beacon, in Wiltshire, a little more than a thousand feet above the level of the sea.

The lowest part of the chalk is composed of hard beds of a grey or mottled appearance, arising from the presence of argillaceous matter and silex.* The green particles of silicate of iron, to which the green-sand owes its name, are found in these junction beds, which contain, however, many fossils of the upper part of the chalk.

As we examine the beds above the marl the chalk is found to contain less alumina, to become whiter and less

* In Lincolnshire, however, and Yorkshire there is found a bed of red chalk at the base of the formation. This colour is probably owing to the accidental presence of a small quantity of iron in the state of oxide.

gritty, and at length to exhibit nodules of dark grey flints, at first few in number and irregularly distributed, but gradually becoming more abundant, and assuming a stratified character as we reach the upper beds. Layers of flints at length alternate with the upper beds of chalk, and are sometimes only a few feet apart. The flints are covered with a white opaque coating, which reaches below the surface, and when broken, every one, without exception, seems to have been formed on some portion of organic matter as a basis. This part of the chalk rarely abounds with large fossils; but, on careful observation with the microscope, it appears that a considerable proportion of the whole mass is loaded with organic matter, and even composed of it to a greater or less degree.*

The chalk, although not met with in the western part of England, in Wales, or in Scotland, reappears in the north-east of Ireland, and there rests, as in England, on a sand with green particles, which is locally called *mulatto*. The close approximation of a mass of igneous rock, round the edges of which the cretaceous system appears, has, in many cases, altered the character of the formation, changing the chalk into a hard limestone or marble; but the characteristic fossils occur, and flints are found, as in England. The whole deposit is said not to exceed three hundred feet in thickness.

* In some localities, however, the chalk is extremely fossiliferous, and in the lower beds, near Bridport, I have been informed by a geological friend, that he observed, in a space containing not more than one-eighth of a cubic foot, the following list of fossils: viz. 9 Spatangi, 9 Scaphites, an Ammonite, and 2 Terebratulæ.

CHAPTER XXXI.

FOREIGN CRETACEOUS FORMATIONS.

The subdivision of the Cretaceous group into chalk and green-sand formations is not confined to England, but extends also over a very considerable part of Europe; and the description already given of the different English beds will apply also to the opposite coast of France in the south, and to the continuation of the group in Denmark in the north. Indeed the white chalk, in its most characteristic form, and usually resting on arenaceous beds, may be traced at intervals from the north-east of Ireland to the borders of Asia Minor, and from Denmark to the South of France; and it again appears, although under another form, in some parts of North America.

In France the chalk occupies a broad girdle, surrounding the Tertiary strata on which Paris is built, and it is known to pass under, and, in fact, form a trough, in which the newer beds repose. It extends westwards to the mouth of the Seine, and northwards into Belgium, covering an immense area, and only occasionally varied by the presence of hard beds, which form a passage from the lower arenaceous beds into the chalk. The white chalk of France is frequently much harder than that found in the south of England, and is often sufficiently compact to be used as a building stone. It contains flints and fossils similar to those of England.

But in the south of France, although there exist deposits contemporaneous with the chalk, they are of a very different mineral character, and differ also in their fossil contents. So great is this change that, in the place of a pure carbonate of lime, forming an opaque white mass, we find the calcareous part to consist of compact crystalline marble, sometimes entirely made up of a peculiar fossil (the *Nummulite*), and overlying a series of shales, grits, and micaceous sandstones, totally unlike the Green-sand of England. These rocks, together with beds of red sandstone and conglomerate belonging to the same group, ascend gradually into the highest part of the Pyrenees, and cross into Spain, where the Cretaceous system assumes a character still more unlike that of northern Europe.*

The lower members of the Cretaceous system in the South of France, in the Canton of Neuchâtel in Switzerland, and elsewhere, have been described by Continental Geologists under the name *Neocomien*, and consist of calcareous beds developed to a considerable thickness, and characterised by some peculiar fossils.

These beds appear unquestionably to be the true representatives of the lower beds of the lower green-sand, as exhibited in the south of the Isle of Wight, and described in the preceding chapter; but it has been suggested, and great efforts have been made to prove, that the beds of the so-called Neocomien formation were contemporaneous, not so much with the green-sand as with the Wealden formation of England, and that they are thus true junction beds between the Oolites and the Cretaceous group. No sufficient proof has, however, yet been given in support of this view, and on the other hand, the Atherfield beds in the Isle of Wight, greatly extended as they are beyond

* Lyell's Elements of Geology. 1st Edit. p. 341.

the usual thickness of the lower green-sand, and unquestionably containing characteristic Neocomien fossils, may be distinctly seen reposing on the Weald clay, the uppermost member of the Wealden group.

Mr. Murchison has well observed of the *Terrain Neocomien*, "the term may be very well and appositely used in reference to the deposit at the base of the Cretaceous series throughout central and Eastern Europe, where its lithological characters are so different from the English type;" but he adds his opinion, that it must, notwithstanding, be the equivalent of the lowest green-sand of England, and of the *hils-thon* of Hanover.*

Returning again northwards we find the chalk extending from the edges of the Paris Basin into Belgium, where the upper strata are principally developed. These consist, at Maestricht, of yellowish and somewhat siliceous beds of chalk, replete with fossils, and they are, in all probability, the newest members of the Cretaceous group in Europe. Siliceous masses abound in these beds, but they are not so abundant as in the chalk, and are composed of chert and chalcedony, instead of black flint. The fossils are interesting, and include amongst them several reptilian remains, one of which, the Mosasaurus, has only been found in the upper Cretaceous beds.

The existence of true white chalk containing fossils like those found in the same rock in England has been clearly determined in some parts of Denmark. Mr. Lyell† describes this formation as exhibited on the shores of the Baltic beneath overlying loam and gravel. It there occupies cliffs partly composed of soft white chalk with flints, and on this a singular yellowish coloured limestone

* Proceedings of Geol. Soc. vol. iv. p. 112.
† Geol. Trans. 2d Ser. vol. v. p. 246.

reposes, containing cretaceous fossils, and overlaid by another chalky rock. The whole sequence has been supposed to represent the newer members of the Cretaceous period, the upper part being contemporaneous with the Maestricht beds.

The east of Europe also contains deposits of the same period as the chalk, although they are not always characterised by the actual presence of that mineral. In Germany it is the lower beds of the Cretaceous system that are chiefly developed, and they are called "Quadersandstein;" but this term is rather applied to any sandstone fit for building purposes, than confined in its use to those of the Cretaceous period. Beds of it are very abundant, in some parts of Westphalia, in the district near Dresden called "the Saxon Switzerland," and also in some other localities. In all these cases the beds contain Cretaceous fossils, and are, probably, the representatives of the green-sand formation, and chiefly of the upper part of it.

Still further to the east, in Poland, the white chalk again recurs, and its lower portion is there marly, and reposes on a true green-sand base, as in England. The Cretaceous beds occupy a considerable space in this part of Europe, and are remarkable for the superposition of extensive beds of gypsum and sulphur upon the chalk marl.

From Poland the rocks of the Cretaceous period extend to the south of Russia, covering the plains of Moldavia, and constituting the western part of the Crimea; and in the districts a little further to the north, the white chalk is stated by Mr. Murchison to be absolutely undistinguishable from that of England, but to repose on a hard concretionary sandy ironstone. Marly beds have

also been observed associated with the Russian chalk, and these are immediately overlaid by white and yellowish subcalcareous marls containing fossils, and probably representing the Maestricht beds.*

But the recent researches of M. Dubois, in the east of Europe and the adjacent Asiatic border, have brought to light an extensive development of the Cretaceous system in the Crimea and the great chain of the Caucasus, which must not be passed by without notice.

It appears that in this district the central ridges which separate Europe from Asia, and which have hitherto been assumed to be of primary origin, are altered strata of the Jurassic period, although resembling the most ancient slaty rocks. These are flanked by huge buttresses of the Cretaceous system, some members of which take the form of fucoid schists, whilst others consist of pure white chalk; so that many parts of the Circassian mountains, broken into striking defiles, and clothed with majestic forests, are simply the representatives of the English chalk downs, with their fringes of green-sand and gault. The continuation into the Crimea is marked by some changes, which, however, approximate the series still more nearly to that of our own country, except that, in those beds which represent the uppermost chalk, Nummulites and a species of Cerithium are stated to be associated with the true chalk fossils.† Lastly, the same series is traceable into the central plains of Asia Minor, where, according to the in-

* Proc. Geol. Soc. vol. iii. p. 728.

† Proceedings of Geol. Soc. vol. iv. p. 112. M. Dubois has determined twelve distinct stages in this Cretaceous system, the uppermost seven of which are referrible to our chalk and chalk marl, and contain many of our well known fossils. The two next seem identical with the upper green-sand, and the tenth with the gault, while the remaining two, called Neocomien, must be considered the true equivalents of our lower green-sand, the lowest of them being considerably expanded.

vestigations of Mr. Hamilton, the Cretaceous beds become semi-crystalline, and are frequently hollowed into basins filled with Tertiary deposits.

The altered limestones of the Pyrenees, and several of the beds which flank the Alps and the Carpathians, belong also to the Cretaceous period, but in mineral structure as well as fossil contents, they differ so greatly from the contemporaneous beds in northern Europe as to require separate consideration. These, or similar beds, are again met with in Italy, forming the well-known but ill understood Apennine limestone, and they exist, in all probability, in the Ionian Islands, in Greece, and in Asia Minor.*

The Apennine limestone is a compact white or greyish coloured bed, very largely developed on the shores of the Adriatic, and possessing a uniform lithological character throughout many thousand feet of vertical thickness of strata, extending over several hundred miles of country. Its age is only approximately determined, as it contains but few fossils available for this purpose; but so far as it has yet been made out the whole series seems to belong almost, if not entirely, to the Cretaceous system. I add, in the form of a note, the most complete account I am able to give of the *Karst* limestone, a very singular rock, probably identical with the Apennine limestone, but developed on the flanks of the Julian Alps.†

* I am happy to be able to state that the Geological structure of Corfu, the largest of the Ionian islands, is now the subject of examination by Capt. Portlock, R.E., who has already noticed some interesting facts, and whose observations are likely to be valuable with reference to the determination of the limestones of the Mediterranean coasts and islands.

† With reference to this difficult subject I venture to subjoin my own notes of the celebrated *Karst* limestone, made during a short visit to Carniola last summer. I have not incorporated them in the text owing to the great doubt that exists in my mind as to the real position of this remarkable bed. It forms the high table-

The Apennine limestone, as it appears in the Morea, has been separated by Messrs. Boblaye and Virlet* into three parts; viz. (1.) The Nummulite limestone alternating with black and micaceous marly beds, and expanded to a thickness of six hundred feet. (2.) A conglomerate overlaid by compact lithographic limestone of very great thickness; and (3) a newer conglomerate and marl, surmounted by white compact limestone without flints, and containing abundant remains of Hippurites and Nummulites; the former fossils being also characteristic of contemporaneous beds in the Pyrenees. A similar subdivision would seem to obtain on the coast of Asia Minor, where, however, the Hippurite limestone is the most characteristic bed.†

Many of the islands in the Grecian Archipelago ap-

land which shuts in the Adriatic to the north, and its surface is hollowed out into curious funnel-shaped cavities, and pierced in all directions by caverns.

"The Karst limestone rises immediately behind the low headland on which Trieste is built, and forms the steep hills which are seen at the head of the Adriatic. It dips to the south at an angle of nearly forty-five degrees, and a kind of ridge, running in the direction of the line of strike at the top of the hill behind Trieste, is composed of it. A range of low hills, whose stratification is greatly disturbed, intervenes between the Karst and the Adriatic sea.

"The ridge of which I have spoken is of a very hard limestone regularly bedded, and having a total thickness of one hundred and fifty, or two hundred yards, and its whole surface is cracked in all directions, and worn into a most complicated series of hollows and trenches. It is highly fossiliferous, but the fossil remains are, so far as I could discover, exclusively those of foraminifera.

"Advancing inland, or towards the north, this hard series of beds is seen to be succeeded by softer beds, containing occasionally corals. These beds are of a pale greyish colour, and still more remarkably broken up into fragments and cracked in all directions. It is here also that the funnel-shaped cavities commence, for which the district is celebrated, and they are so numerous that the whole country appears to be covered by them. They continue for many miles, usually measuring from twenty to fifty yards in diameter, but some much larger. They are clearly *not* connected with lines of fault, but are probably caused by the sinking in of the roofs of some of the innumerable cavities hollowed out in the substance of this singular limestone."

* Expedition scientifique de la Morée. Paris, 1835.

† Trans. Geol. Soc. 2d Ser. vol. iv. p. 1.

pear, as might have been expected, to partake of the same Geological structure as the Morea, and the Hippurite limestone is also well shown at Smyrna, and at the south-western extremity of the Gulf of Cos; but all the beds are here very much disturbed, the limestones of the Cretaceous system being elevated into mountain chains, and having acquired a compactness of texture, and a peculiar mineral character, much more like that of the Palæozoic and altered rocks than the Secondary strata as they are exhibited in northern and western Europe. The fossils, also, are rare in these localities, and in many districts have been sought for in vain.

HIPPURITES BIOCULATA.
LAMK.

But it is not only in the south of Europe that the Cretaceous rocks have undergone a change, for in some parts of the Alps, at least as great an alteration may be readily pointed out. The Canton of Glaris, in Switzerland, has long been known as a locality for fossil fish; and these occur in a black slate exactly resembling the slates of the Palæozoic period, but now known to represent an altered condition of argillaceous rocks of the age of, and probably resembling, the gault of our own country.

I have already mentioned that the coast of Asia Minor repeats, to a certain extent, the geological structure of the Morea, and that the same may be remarked of the intermediate islands. The islands and shores of the Gulf of

Syme are, however, composed of a mass of compact white scaglia, or chalk, with bands and nodules of siliceous limestone. The greater part, also, of the island of Rhodes, and part of Syria on the Lebanon range, immediately above Beyroot, are composed of chalk and cream-coloured limestones with flints, containing a few fossils, and amongst the rest the Hippurite.

A limestone, containing fossils nearly allied to Hippurites, and belonging to the Cretaceous period, has been described by Mr. Sharp* as occurring in the neighbourhood of Lisbon, and there is reason to believe that similar rocks are repeated in various parts of the Peninsula. The bed above alluded to is traceable for a considerable distance north of the Tagus, and the hills composed of it form a prominent feature in the landscape. It is of considerable thickness, and is made up of soft argillaceous limestone and beds of marl, alternating with fossiliferous strata, and with beds of hard compact limestone of a white colour.†

The newest Secondary deposits of America correspond with tolerable accuracy to those of the Cretaceous period, but they rest immediately on the oldest Secondary rocks (those of the Triassic period), without the interposition of the Oolitic group. There is thus, in that great con-

* Trans. Geol. Soc. 2d Ser. vol. vi. p. 107.

† I ought not to conclude this sketch of the Cretaceous rocks of Europe without alluding to the beds in the Valley of Gosau in the Styrian Alps, which were described by Messrs. Sedgwick and Murchison as probably forming a group intermediate between the chalk and the Tertiaries. (See Geol. Trans. 2d Ser. vol. iii.) It has appeared from more minute observations made since their visit, that the existence of a passage between Secondary and Tertiary strata in this part of Europe, is not borne out by the evidence resulting from a careful examination and comparison of fossils, and there is little doubt that the chief part of the Gosau formation is of true Tertiary origin, and that the underlying beds are referrible to the chalk.

tinent, a hiatus nearly as remarkable between two members of the great Secondary system as there is in Europe between the Secondary and Tertiary beds.

There is said to be no true chalk in North America. The calcareous deposits of the Cretaceous period occur in thin horizontal layers interstratified with blue clay, or resting immediately on friable sands and marls. They consist, (1) of an extremely friable mass almost entirely composed of fragments of corals; (2) an extremely compact limestone of a yellowish colour; (3) a subcrystalline limestone intermediate in character between the other two; and (4) lastly, a white limestone; the whole series being loaded with Cretaceous fossils. These beds, and the underlying arenaceous strata, are of great thickness, and extend from New Jersey (where they first appear) in a south-westerly direction across the continent of North America to Louisiana, and then taking a northerly bend they flank the great range of the Stony mountains. It is remarked concerning them by an American Geologist, that these various deposits in the states of New Jersey, Delaware, Maryland, Virginia, North and South Carolina, Georgia, Alabama, Mississipi, Tennessee, Louisiana, Arkansas, and Missouri, though seemingly insulated, are doubtless continuous, or nearly so, forming an irregular crescent nearly three thousand miles in extent; and that there is not only a general accordance between the fossil shells scattered through this vast tract, but in the far greater number of cases, those species which are most characteristic are found throughout, without a shadow of difference, from New Jersey to Louisiana.*

Although, however, there is to a certain extent a ge-

* Report on the Geology of North America by Prof. Rogers. Fourth Report of the Brit. Assoc. p. 51.

neral resemblance between the different Cretaceous rocks of North America there are also some striking exceptions; and in North Carolina, for instance, black shales occur, which have been proved, by the incontestable evidence of fossils, to belong to the period we are considering. But these exceptions ought not to excite surprise, and we should rather be astonished at the remarkable uniformity observable over extensive tracts than at such occasional differences.

Deposits of the Cretaceous period appear to have been extensively developed in many parts of the South American continent, and recent researches would tend to show that they may be traced along the whole country from Columbia down to Tierra del Fuego. They are supposed by M. d'Orbigny to belong principally to the lower part of the series, and they contain several species of fossil shells which have been identified with those of Southern France. A fossiliferous limestone in Brazil also contains the remains of fish, which have been referred by M. Agassiz to the same date.

The south-eastern part of the peninsula of India has lately yielded fossils apparently of the Cretaceous period, and the discovery of these well-preserved organic remains must act as a strong incentive to the prosecution of further researches in this part of the British Empire, where so much yet remains to be done in many departments of scientific investigation.

In a district so widely removed as Southern India from all kinds of resemblance to North European types of animal and vegetable life, it is not surprising that little identity should exist between the fossils of the two countries, even if the deposits in which they occur were actually contemporaneous. It is chiefly by their general character

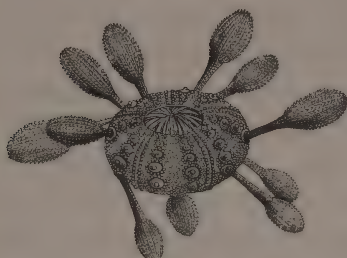
that the fossils can be referred with certainty to the same period, but the evidence appears sufficient to warrant the conclusion, either that they are strictly Cretaceous (belonging, probably, to the period of the lower green-sand) or, perhaps, that they represent that intermediate period during which our Wealden beds were being deposited. The principal localities from which these fossils have as yet been obtained, are in the Carnatic, and in the neighbourhood of Trichinopoly and Pondicherry.

The subjoined vignette belongs rather to Chapter xxv. than to the present place. It represents an interesting locality in Switzerland, where the Secondary Rocks (almost entirely of the Oolitic period) form picturesque and bold mountain scenery, and enclose lakes fed by mountain streams, which often empty themselves in lofty cataracts.

LAKE OF BRIENZ—SWITZERLAND.

CHAPTER XXXII.

THE FOSSILS OF THE CRETACEOUS SYSTEM.



CIDARIS CLAVIGERA. Koenig.

Although the passage from the Weald clay to the Lower green-sand seems to take place sometimes by an alternation of deposits, the clay becoming sandy, and this arenaceous clay passing into a sand with green particles, there is still a test which may be invariably applied, and which will determine at once the boundary line of the two formations. As I have already observed, the fossils of the Weald are those of land and freshwater animals, but the moment we have passed the limits of this formation, the character of the fossils changes entirely; we have no more remains of freshwater shells, and if at first there are a few indications of gradual alteration in the occurrence of fragments of silicified wood, and the bones and teeth of land reptiles, these soon vanish, and are replaced by the remains of animals strictly marine.

The fossils of the Cretaceous series differ thus entirely from those of the immediately underlying deposits, and, as might be expected, they also differ exceedingly from those of the Oolites, but notwithstanding the length of the interval indicated by the deposit of strata at least 1,000 feet in vertical thickness, this change is not complete, although doubtless very strongly marked. The general character also of the fauna is not so greatly altered as might seem to be indicated by the number of new species introduced; but, on the other hand, we find circumstances of deposition producing very decided and total changes, so that, in the Hippurite and Apennine limestones, whole groups of fossils are characteristic of particular localities, and scarcely appear at all in others.

The remains of plants are exceedingly rare in the Cretaceous formations of England, but occur in sufficient abundance in the contemporaneous sandstones on the continent of Europe. Here, for the first time, there appear leaves of dicotyledonous plants, while fragments of wood referred to the same division have been found in the green-sand, and also in the chalk. These fragments are usually much marked with the perforations of marine worms (the *Teredo*), indicating that they had been floating about for a long time in the ocean.

Of all the fossil remains of the Cretaceous system, perhaps the most remarkable are those obtained from the flints which so singularly abound in the upper chalk. These have been examined with great care by Mr. Bowerbank,* and he has arrived at the conclusion that, in all cases, the siliceous matter has formed itself on organic bodies, and that these organic bodies are the very lowest of their tribe, being in fact sponges, which, as I have

* Trans. Geol. Soc. 2nd Ser. vol. vi. p. 181, *et seq.*

already observed in speaking of their classification, scarcely exhibit more marks of life than the solid rock to which they were affixed.

But the structure of these singular animals (if so they may be called) is exceedingly interesting, both as exhibiting the very simplest form in which inorganic matter enters into relations with organic life, and also because we are by them enabled to trace the marks of organisation in the structure of the apparently shapeless flints, whose appearance in the chalk it is so difficult to account for.

The common sponge is known to be made up of horny elastic fibres of great delicacy, united with each other in every possible direction, and thus forming innumerable capillary canals. The dried sponge of commerce is only the skeleton of the animal, and in many species it is found to contain great quantities of crystallized spicula, sometimes calcareous, and sometimes siliceous, united together by the tenacity of the fibres by which they are surrounded.* Such spicula have determinate shapes, generally in relation with the natural form of the crystals of the mineral substance of which they consist, and the shape of the spiculum is found to be similar in all sponges of the same species.

The growth of sponge takes place by the continual accumulation of a thin film of glairy semi-fluid matter, which surrounds the sponge in a living state, and, spreading in every direction, secretes and deposits in the form peculiar to its species the fibrous materials and earthy spicula which characterise the skeleton. The filaments which compose the horny skeleton are found on examination under the microscope to be tubular.

* Rymer Jones's Outline of the Animal Kingdom, p. 14.

Now whenever thin polished slices of the common flints of the chalk are subjected to examination under an excellent microscope, with a power of about 120 linear,* they are found to exhibit the appearance of a mass of numerous cylindrical contorted canals, the walls of which seem to have been formed of a thin net-work, like the reticular substance of the common sponge, and amid the mass are found spicula and minute shells, imbedded in a manner precisely similar to that observed on a larger scale in the recent Mediterranean species. Even in those cases in which the reticulated substance of the sponge does not exist, its presence is often indicated by the arrangement of the particles of the siliceous matter, which are moulded into the form of the tissue, amid which it was deposited. At other times this substance is apparent by the position of the spicula, suspended equally in all parts in their natural position, for it is thus clear that the organized tissue in which they were entangled retained its form and texture sufficiently long to allow of the perfect fossilisation of these remains in their original places. It would seem as if the sponges, which under certain circumstances had grown and flourished at the bottom of the sea, had been at successive periods covered up by fine calcareous mud deposited gradually upon them; that the particles of fine mud, thus sinking gently from suspension in the water, had barely penetrated below the surface of the sponges, resting upon them, but not flattening them by the pressure; and finally that, owing to some chemical cause, a deposit of siliceous matter being in progress, the particles of silex were attracted to these organic bodies, themselves containing some portion

* Bowerbank, loc. cit. p. 182.

of the same mineral.* It appears that we can in this way, and in no other, account with any degree of plausibility for these three phenomena, viz.:—first, for the existence of beds of flint in the chalk; secondly, for the organic structure visible in the flints, and the frequent occurrence of fragments of corals, shells, and zoophytes, imbedded in them; and, lastly, that in some cases large silicified sponges are found growing vertically, one upon another, to a height of several feet in the chalk; and that sponges now silicified have often grown through and over the shells of Echini, or Molluscous animals, and even of other sponges.†

a. VENTRICULITES RADIATUS. MANTELL.
b. SIPHONIA PYRIFORMIS. GOLDF.
c. CARYOPHYLLIA CENTRALIS. PARK.

Among the most abundant and characteristic of the extinct spongiform bodies of the Cretaceous period are those which have been named *Ventriculites*, *Choanites*,

* This presence of particles of the same mineral on which the silica aggregates, is probably not at all essential to the progress of silicification. There certainly appears to be a very great and singular tendency in silica to form itself upon organic matter, but whether Mr. Brown's strange and startling theory of the convertibility of carbon into this mineral may, if true, account for the tendency, it is, perhaps, somewhat premature to speculate. At all events, the fact seems worthy of remark.

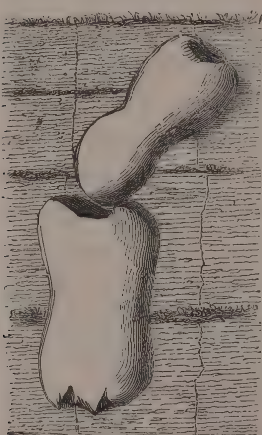
† See Annals of Nat. Hist. vol. xiii. p. 241, *et seq.*

Polypothecia, *Siphonia*, and *Paramoudra*. As many as twenty-one species have also been referred to the genus Spongia, from the British Cretaceous formations only.

Of these genera, the *Ventriculite* is found of various shapes and sizes, and its original texture was evidently soft, and yielding readily to pressure. It appears to have possessed externally a reticulated surface, the inside being porous, and bearing considerable resemblance to dried sponge.

Specimens occur having every intermediate form between that of a simple elongated cone and a flat circular disc, the thickness of the sides being considerable when the cone is short, thinner when more extended, and thinnest when completely expanded.

The *Choanites* differ from Ventriculites by the possession of a circular opening in the upper part, which continues gradually diminishing to near the base. The general proportions are also somewhat different, and the dimensions smaller.



PARAMOUDRA.

The *Paramoudras*, or Potstones, are only common in particular localities; and they there attain a considerable size, measuring from one to three feet in height, and about half that in diameter. They are chiefly found in the North of Ireland, and in chalk quarries near Norwich, and are generally insulated in the chalk, sometimes lying horizontal, and sometimes inclined or erect, but although silicified, not apparently connected with the layers

of flint. These singular fossils are cylindrical, fusiform, or cup-shaped, and they are occasionally found planted, as it were, one above another, the upper one being closed at the top, and attached to the open lip of that immediately below. They all have a hollow open axis filled with chalk, and a central tube about the thickness of a finger, consisting of siliceous particles, is traceable through the chalk from the base to the vertex. The different species of all these three genera were doubtless affixed by roots to the solid rock, and possessed no powers of locomotion.

The *Polypothecia* was a branching sponge, and in this respect differed from the cup-like forms assumed by the other genera. It also seems to have been frequently enclosed and built round by others, so that it is not unusual to find chalk flints, apparently shapeless, but which when broken open are found to contain a hollow space, partly filled by the silicified remains of one of these organised beings.

The *Siphonia*, of which I have figured a common species from the green-sand, differs somewhat in general appearance from the other sponges of the Cretaceous system, but agrees in all points of structure. It is often met with of large size, and mounted on a long stalk, the lower end of which was attached, as such sponges still are at the present day, to a stone or rock.*

Amongst these sponges silicified in the chalk, there are not unfrequently found very minute siliceous skeletons of animals, which can only be seen by the aid of a good microscope, but which are then found to represent those

* These remains of sponges are exceedingly abundant and well developed on the Yorkshire coast, near Bridlington, where they lie exposed in great numbers, and not being encased in flint, their organisation may be studied with the greatest advantage.

infusorial animalcules, known to exist in stagnant water. Some of these (*e. g. Xanthidium*) are of very singular and beautiful shapes, and they have apparently become entangled in the reticulated texture of the sponges before the process of fossilisation commenced.

The subject of these animalcules belongs, however, rather to Tertiary than Secondary Geology.

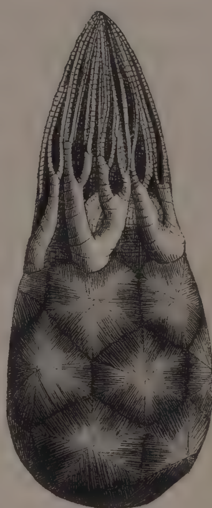
Fossil remains of what are called foraminated shells (so named from the presence of a small opening or *foramen* in the walls or *septa*, which separate the shell into a number of chambers) have been found in great abundance in some Cretaceous rocks in the Mediterranean; * but as such fossils, like the smaller infusorial animalcules just alluded to, are, perhaps, on the whole more characteristic of the Tertiary period, I shall reserve the remarks I mean to offer on the subject to a future chapter. They appear to have been the habitations of animals of very low organisation, although they were originally described by M. d'Orbigny as forming a group nearly allied to Cephalopoda.

The Radiated animals, whose remains are found in the different beds of the Cretaceous period, exhibit several varieties of form, and possess considerable interest. They include some existing genera, besides many which are not now represented.

The *Marsupite* is a fossil of somewhat remarkable kind, indicating a curious passage from the attached encrinites to the Spatangi and sea urchins. The shell closely resembles that of the encrinites in the structure of the cup-like receptacle for the animal, which is made up of hexagonal plates, the edges of which overlap. To the

* One genus also (*Spirolinites*) has been frequently found associated with *Xanthidium* in the silicified sponges of the English chalk.

upper plates were attached others, from which arms proceeded, covered no doubt with fingers or tentacula, but to this stony case there was no column whatever fastened, and the animal was, therefore, enabled to swim freely in the ocean. Besides the Marsupite some true encrinites occur in the chalk, and amongst them a species of Apiocrinite.*



MARSUPITES ORNATUS.
MILLER.

In several localities, both in the chalk and in the associated sands, the remains of those genera of echinodermata still represented in our own seas are exceedingly abundant, the species being of course distinct. These are occasionally found in admirable preservation, and I have figured at the head of this chapter one specimen of *Cidaris*, which in the attachment of the spines, and the existence of the dental apparatus *in situ*, is especially interesting. The odd club-shaped spines, projecting from the shell, are composed, as in the living allied species, of carbonate of lime, distinctly crystalline, and are attached to smooth solid balls of the same substance, on the external surface of the polygonal plates of which the shell is made up. The spines also have sockets at their bases, permitting an accurate application to the spherical surface of the tubercles, and they thus constitute ball and socket joints, allowing of free motion in all directions. Each joint is connected with the plate in the living animal by means

* See *ante*, page 391.

of the skin or integument, and sets of muscles are provided for working the spines, by using which as levers, the animal advances with great facility along the surface bottom of the sea.

The dental apparatus consists of a frame-work of shell, comprising five pieces, each armed with a long tooth. The teeth are calcareous prisms, three-sided, dense at the working apex and softer at the base, with the inner edge sharp, and fit for cutting.

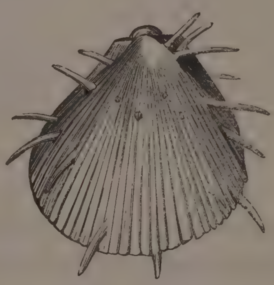
The genus *Salenia* of Agassiz, which differs from the other Echinodermata in the unsymmetrical position of its aperture, is also common in some beds of the green-sand formation in England. At least half the English species have been obtained from one locality (the neighbourhood of Warminster), particularly rich in these fossils.

The calcareous plates of Starfishes (Asteria, or more probably Goniaster) are common in some parts of the chalk, but the facility with which the plates are detached after the death of the animal renders it extremely difficult to obtain specimens in a perfect state.

The crustaceans of the chalk comprise several species, not widely different from those of the present seas, and representing the more highly organised groups, in contradistinction to the Trilobite and other crustaceans of a lower type in the older formations. The calcareous covering of these animals is not usually so well preserved in the chalk as one might have expected, and specimens are found more perfect and in better condition in the green-sand than in the newer part of the cretaceous group. Perhaps the most interesting of these crustaceans is a species which has been referred to the genus *Pagurus* (*Hermit crab*), and which is found commonly at Maestricht. It is only the claws of this animal that are met with in a fossil state, a

fact readily explained when we consider the habits of the tribe of crustaceans to which it belongs.

It is well known that a common species of crab on our own shores seeks for the empty shell of a Whelk, and, taking possession of this fortress, remains there until its increasing size requires a similar and more convenient dwelling place of larger dimensions. A habit so singular is founded on the structure of the animal, which does not secrete shelly matter except on the claws, the body being left naked. These hermit crabs, as they are called, were common in the seas of the Cretaceous period, and then, as at the present day, the empty shells of mollusca were turned to account by animals of such different organisation; and remains have been handed down to us in beautiful evidence of the uniformity of action of the laws of animal existence in the midst of successive and never-ceasing change.


PLAGIOSTOMA SPINOSUM. Sow.

Numerous fossil shells are found in all the beds of the Cretaceous group. The Terebratulæ are abundant and characteristic, but do not exhibit any new form, or greatly differ in appearance from species to which we are accustomed in older formations. The *Plagiostoma*, a genus of bivalve shells not unlike the *Spondylus*, is represented by a singular species covered with long spines (*P. spinosum*).

The *Inoceramus** is another genus often growing to a large size, and having a long hinge and a peculiar structure of the shell. Many others also might be quoted.

* See cut, p. 455.

But the Rudistes, which form an extinct family of molluscs, may perhaps be considered as, in some respects, the most interesting of all the Cretaceous bivalves, both because of their singular structure and doubtful analogies with known species, and also because they are the most abundant and most characteristic fossils of some important members of the Cretaceous series in southern Europe. The geological position of these beds is probably identical with that of the lower chalk containing green grains, found in the south of England, and from the abundance of individuals of the same species in the same locality, the gregarious habits of the animals are clearly indicated.

M. A. D'Orbigny,* after giving great attention to a vast number of specimens of these singular shells, with a view to discover the nature of the animal inhabitants, has come to the conclusion that they were true Brachiopodous molluscs, and in this opinion he is supported by M. Goldfuss. The peculiar fibrous, lamellated, and porous structure of the shell, the gradual passage of the more anomalous forms, such as the *Hippurite*,† through the *Radiolite*, to the *Crania*, (a known Brachiopod,) and the general appearance of the interior of the shell, all seem to indicate the approach, so that we may now, according to these naturalists, divide the Brachiopoda into two orders: the first containing the Terebratula and other genera, in which the animal is usually able to attach itself to an extraneous body by a tendinous or fleshy cord, the shell itself being free; while the second order contains the Rudistes, whose shell adhered by the lower valve to a rock, the animal having no power to detach itself, and being confined within the shell by deep and broad muscular attachments.

* Annales des Sciences, tom. xvii. Zool. page 173.

† See cut, p. 466.

The Cephalopoda, the most highly organised of the mollusca, are also among the most numerous fossils found in the Cretaceous rocks, and several complete genera are confined in their distribution to this period. It is not a little singular to observe the numerous and apparently capricious forms which these Cephalopoda put on. In addition to the *Nautilus*, the *Ammonite*, and the *Crioceratite*, we find also the *Hamite*,—an Ammonite with the final whorl extended and changed into a hook; the *Turrilite*,—an Ammonite wound spirally, but not in one plane (resembling

a. HAMITES ATTENUATUS. Sow.
b. SCAPHITES ÆQUALIS. Sow.
c. TURRILITES COSTATUS. Lam.

in this the turreted shells); the *Scaphite*,—a Hamite, in which the portion extending beyond the central spire turns back towards it in a boat-like form; and the *Baculite*,—an Ammonite entirely unwound and straight, resembling therefore the Belemnite in shape, but differing entirely in the arrangement of the chambers. All these, and many other forms of multilocular shells of Cephalopoda, abound in the beds of the Cretaceous period; and although differing in some details, all of them are constructed on the same principle, namely, that the periodical secretion of shelly matter in the animal, instead of being employed in forming projecting spines, as in the *Murex* and other Gastero-

poda, is deposited in the form of a septum or wall, shutting off a portion of the shell formerly inhabited. This portion, when built off, is left filled with a light gas, and the animal thus gradually constructs for itself a balloon, by means of which it can rise to the surface of the water, and which, combined with a power of ejecting currents of water through a strong muscular funnel, gives it full liberty of motion in every direction.

BACULITES FAUJASII. Sow.

The Baculite presents an interesting form of these many-chambered shells as contrasted with the Orthoceratite and the Belemnite. The shell seems to have been exceedingly elongated and conical, but depressed laterally, and divided by numerous septa, offering a line of intersection with the shell exceedingly complicated. The external chamber is much larger than the rest, and capable of containing a considerable portion of the animal, but it is not improbable that the mantle was continued over the whole shell. The position of the siphuncle is dorsal, as in the Ammonite.

The commencement of the Cretaceous period seems to have been marked by the introduction of a vast number of new species and genera of fish, almost the whole of them belonging either to the Ctenoid or Cycloid order of M. Agassiz. The result arrived at by thus adopting this

Naturalist's method of arrangement of fish by the peculiarities of their scales, is exceedingly remarkable in the extent to which it separates the Cretaceous from the Oolitic formations, as in the latter are found the remains of as many as ten of the most important Ganoid and Placoid families, and not one Ctenoid or Cycloid, while the former introduces as many as eighteen families of these latter orders, associated with such of the two others as pass also into the Tertiary formations. Of these the Pycnodonts compose the only family not now represented; but the Sharks, the Port-Jackson Sharks, and the Rays, among the Placoid, and some few of the Ganoid fish, still remain, although they are rare, and of diminished size and ferocity. The *Macropoma*, nearly allied to the fish of the Sauroid family, is confined to the chalk, where it is not unfrequently found, and its coprolites are exceedingly abundant in particular localities.

The Macropoma being one of the latest representatives of a very remarkable group of fossil fish, characterised by the presence of a cavity in the rays of the fins, is an object of considerable interest to the Ichthyologist. It seems to have been between eighteen inches and two feet in length, elongated in form, and slightly compressed. The head occupied one third of the entire length of the animal, and was provided with jaws armed with numerous sharp conical teeth. The body was covered with rhomboidal scales, studded with hollow tubes, and the dorsal fins were powerful, especially the anterior one, which was strengthened with spiny rays. The skeleton is of robust proportions, and the spines with which the rays are studded doubtless served as a defence for the animal. Like the other fish of the Secondary

period, the vertebral column does not pass into the tail but is terminated as in recent species.*

OSMEROIDES MICROCEPHALUS. AG.

The genus *Osmeroides*, of which I have figured a beautiful specimen from a foreign locality, is also found in the lower chalk of Sussex. This genus has received its name from its great resemblance to the *Smelt*. It belongs to the Salmon family, and is, therefore, interesting in its analogies with existing species of fishes.

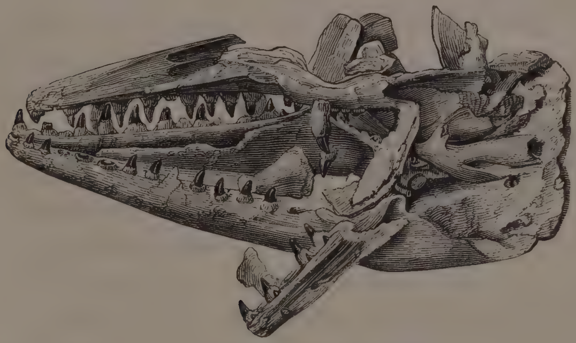
Another remarkable fish of the chalk has received the name of *Beryx*, and bears some resemblance to the Dory. It is of the Ctenoid order, the edges of the scales being jagged like the teeth of a comb. It is not more than six or eight inches long, but the scales are large, and covered with striæ. The lower jaw is straight, the upper one slightly arched, and both are destitute of teeth. The remains of this fish are more abundant than those of any other species in the chalk, and some specimens have been found of extreme beauty, one of which was a principal

* M. Agassiz observes of this genus, that he has seen several specimens in which there were not only the gills preserved, but also *the whole stomach* with its membranous walls solidified, and with coprolites in the abdominal cavity.—*Poiss. Foss.* vol. i. p. 182.

ornament of Dr. Mantell's Collection (now in the British Museum,) while another, perhaps yet more instructive, adorns the cabinet of Mr. Bowerbank.

The teeth and palatal bones of large fish (*Lamna*) nearly allied to the Shark, are exceedingly common in some parts of the chalk, but they are usually detached and single, on account of the cartilaginous nature of the jaw in which they were imbedded. They are of various shapes, having been derived from different parts of the mouth, which in all squaloid or shark-like animals is provided with several rows of sharp teeth. Fins, or bony spines, (Ichthyodorulites) are also found in the chalk and still more frequently in the green-sand.

The class of Reptiles was represented during the Cretaceous period by several very remarkable genera, one of which has received the name MOSASAURUS, having been found originally on the banks of the Meuse, in the celebrated quarries of St. Peter's Mount near Maestricht.



MOSASAURUS HOFFMANNI. CONYBEARE.

The Mosasaurus is a genus determined from a fossil discovered upwards of sixty years ago, and which, at that

time, was extremely puzzling to Naturalists. Its true place in the animal kingdom is now known to be among the Lacertian Saurians, but the animal appears to have been perfectly marine in its habits. The head, the only part at first discovered, measured four feet in length, and is preserved in the Museum at Paris. Other parts have also been found from time to time in the Maestricht quarries, and some fragments in the chalk of the south of England.

The genus of animals now living to which the extinct Mosasaur is most nearly allied, includes the "Monitor," a Lacertian Reptile met with in Egypt, where it attains a length of five or six feet. The animals of this genus have a long tail compressed laterally, and are usually more or less aquatic in their habits, though always living near shore. The head and teeth of the Mosasaurus exhibit a near relation to the Monitor, but the head alone is as large as the whole body of the recent species, and the teeth are of a size proportioned to that of the body, and are solid, being united to the socket by a broad and firm base of bone. They are thus exceedingly strong, and were constantly renewed by young teeth pressing against the bases of the old ones, and gradually pushing them away and replacing them.

The vertebræ are like those of the swimming Crocodilian animals, but are destitute of any processes which could interfere with the easy and universal flexion of the back bone in swimming: the neck is, also, more flexible than in Crocodiles, and the tail was flattened on each side in a vertical direction, forming a straight oar of great strength, corresponding both with the size of the animal and with the large paddles which it possessed. In the proportions of these latter it must have rivalled even the Plesiosau-

rus, and the whole length to which the animal may have attained could not be less than twenty-four feet, a magnitude which must be compared with that of the Lizards, to which it was closely analogous, and not with the Crocodilians, whose structure is totally different.

Another genus has been described whose remains are found in the English chalk, and which is closely allied to the Mosasaurus, but of only half the dimensions. The teeth of this genus (named by Professor Owen, *Leiodon,*) differ only in some points of detail from those of its larger analogue. Besides these a third Lacertian of much smaller size has been determined from some imperfect fragments in the chalk and green-sand: and in the lower beds of the latter formation (at Hythe) there occur other remains of a Crocodilian of gigantic size. As these latter consist only of bones of the extremities they cannot be referred at present to any known genus, but they evidently belonged to an animal of marine habits, and its dimensions may be in some measure imagined from the proportions of the femur, whose length alone is as much as four feet six inches—more than double that of the Pliosaur, the gigantic Saurian of the Kimmeridge clay.

The remains of Marine Turtles have been met with in England in the green-sand, and even in the chalk, but they are very rare. Similar fossils also occur in the Glaris slate, and in the Maestricht beds, and they all approximate in their structure to existing marine genera, having the middle toe of the fore paddle much longer than the rest; whereas, in land Tortoises, all the toes are of equal length and short, and in freshwater species, they are also of equal length, although not so short in proportion as in those inhabiting the land.

Lastly, the chalk of the south of England has preserved in some very few cases the remains of BIRDS; and a bone, or rather three fragments of bone, of animals of that class, have been described by Professor Owen in the Transactions of the Geological Society.* These fragments are referred to a large and powerful species equalling in size the Albatross, but differing from that genus in some important details. No fragment of any Mammalian animal has yet been discovered in the formations of the Cretaceous period.

The subjoined vignette represents a very celebrated locality for *Gault* fossils.

VIEW OF FOLKSTONE UNDERCLIFF.

* Second Series, vol. vi. p. 411.

CHAPTER XXXIII.

GENERAL REMARKS ON THE STRATA AND FOSSILS OF THE SECONDARY PERIOD.

If the reader, having made himself acquainted with the facts detailed in the preceding chapters, will now pause and consider the general nature of the strata referred to the Secondary period, and compare them with what he has learned of the usual condition of rocks of the Palæozoic period, he will perceive that a manifest and important change has supervened; but that this change, very strongly marked when groups of strata belonging to distant epochs are brought under review, is nowhere really so sudden as to indicate any necessity for the assumption of violent alterations in the mode of administering those laws which have governed the material universe.

In the lowest rocks, and therefore, as we assume, in the earlier periods of the earth's history, we have found that the beds chiefly consist of coarse conglomerates, micaceous grits, and great thicknesses of mudstone, including lenticular masses but no beds of limestone, and with these are associated, or to these succeeded other limestones in a crystalline state; whilst an air of antiquity pervades the whole series, and innumerable cracks and fissures in the strata, and the frequent re-arrangement of the particles of the rocks attest changes and alterations of condition, which, although not necessarily the effects of age,

might, at all events, be more reasonably expected in the older than in the more modern formations.

Contrasting these with the appearances presented by the rocks of the Cretaceous or Oolitic period, I need hardly say how striking and complete the change appears. In these latter strata, as they are exhibited in our own island, there is an aspect of newness, which sometimes interferes with the attainment of a proper feeling of their really vast antiquity. If they are, relatively to the former group, said to be of modern date, how may we properly express our sense of the ages that must have intervened before the newest of the Secondary rocks were covered up by the long and varied series of Tertiary deposits?

But this contrast between the Palæozoic and Secondary rocks, although sometimes so striking, is after all in many cases more apparent than real. The older strata are not always developed as we see them in some parts of England, nor are the newer always so little disturbed, and formed of materials so uniform in their nature.

The New red sandstone and its associated beds, the sandstones of the Oolites, and those of the Cretaceous system, all point to a cycle of formations; for all are associated, under circumstances somewhat similar, with clays and calcareous beds, and all exhibit such local varieties as, on the whole, indicate a perfect system of alternations, carrying us through the whole period, and proving that there must have been a frequent repetition of similar conditions in the mechanical and chemical origin of widely distant beds.

But, perhaps, it will be advisable to recapitulate very briefly some of the facts recorded in the preceding chap-

ters, where we have been contemplating a long succession of regularly deposited strata, formed of various but constantly changing proportions of sand, calcareous matter, and clay, and whose total thickness amounts to several thousand feet.

These materials, which have been placed in their present position not without a considerable degree of uniformity of action over extensive tracts, form a number of groups, amounting to nearly thirty, each of which possesses some general characteristic peculiar to it, and by which it may be distinguished. Each appears to have been formed under water, and to have had for the most part a marine origin, and there can be no doubt that, although now indurated and forming hard stony beds, all of them, with the exception of some coralline limestones, were originally loose sands or mud. The order in which these deposits took place may be thus shortly stated.

Immediately after the conclusion of that period which we have designated Palæozoic, many circumstances render it probable that an interval took place in the progress of marine deposits, at least so far as our own island and the continent of Europe were concerned. With the cause of this we have nothing here to do, but the reasons for supposing such an interval are derived, not only from an examination of the fossils of the older Secondary and newer Palæozoic rocks, but also from a consideration of the manner in which the newer beds were subsequently superimposed.

After the termination of this interval, of whose magnitude we have no measure, the great masses of sandstone in the deposits immediately succeeding, and which form, with the Muschelkalk, the Triassic system, are very remarkably analogous to the sandstones of the

Upper coal-measures and the magnesian limestone series, and indicate that no change at all, or very little change, had taken place in the mechanical conditions of the deposit.

But, arrived at this point, we enter upon the consideration of differences of another kind, those, namely, of the species of animals and vegetables whose remains are found fossil in the different beds; and from them we draw conclusions far more satisfactory than those arrived at by the examination of the deposits themselves, but entirely in accordance with them. The fossils of the newer or Secondary period differ considerably in specific character, but not by any means so greatly in the general appearance of the groups, (which is a matter of higher importance) from those of the older or Palæozic period. The difference is, however, as I have endeavoured to show, one of a peculiar kind, and indicates progressive change by means of a gradual approximation to the fauna and flora of a more recent period, in which races are developed having on the whole a more complex organisation. That this, as a general statement of the nature of the organic changes that have succeeded one another upon the earth, is strictly true, and has been fully made out, I do not hesitate distinctly to assert. But it is a point of great importance in Natural History, that it should be distinctly proved; it is one of those generalisations which, if true, casts a new ray of light upon the labours of the humble student of nature; it is one which must help practically and immediately to affect the progress of science; and therefore, it has with great propriety been admitted slowly and with caution; it has been controverted and discussed, and will, perhaps, continue to be doubted by some, but I think it may safely be said that no

one, who has pursued the study of fossils in connection with Geology, can now for a moment question its accuracy.

Feeling its value and importance, it has been my main object, in those chapters in the present work which have reference to Palæontology, that the subject should be put before the reader as a plain and straightforward history. I would now request him to recal, so far as he is able, these descriptions, and reproduce, as it were, in his imagination the inhabitants of the earth at those successive periods which I have taken as posts of observation in describing geological facts; and doing so, and assuming that my descriptions and deductions are sufficiently in accordance with truth and probability, I think he cannot refuse his assent to the generalisation just stated.

The matter is indeed now brought within a narrow compass. It is asserted that there are many distinct groups of organised beings, known to us by their remains, which are handed down in different beds of limestone, sandstone, and clay; that these groups are in beds which lie one over another, and of which the lower were therefore first formed; and that the groups are sufficiently extensive to indicate, more or less completely, but always relatively, the actual condition of animal and vegetable life at the time the beds containing them were deposited. If then, by the study of such fragments as are found in these beds, we are enabled to learn the general appearance and analogies of the organised beings to which they belonged, we are in a condition to prove the truth of the above assertion, and we may safely generalise to the extent I have at present ventured.

But the conclusions arrived at, with reference to the magnitude of the hiatus existing between rocks of the Secondary and Palæozoic period, depend upon the relative

value we may be inclined to affix to a certain amount of change in species and groups of species; and this is a subject on which much knowledge is still required. It must not, however, be supposed that any, even the smallest, doubt is thrown on the reality of the conclusion, "that a change of the species occurring in two strata indicates a lapse of time;" nor has this consideration anything whatever to do with the main fact, that species once lost sight of in a stratum are never restored in any bed of newer date, or that, looked upon with reference to natural history generally, there is any question of the actual change tending *on the whole* to more perfectly developed forms of life.*

The actual observations of a competent and careful naturalist, even in a very limited field, and with reference to a single locality, are, however they may need confirmation in other districts and under other circumstances, far too important, with reference to this subject, to be omitted

* I am very particular in limiting this statement to the general result. It is *not* true—it is, on the contrary, distinctly disproved by every day's research in Palæontology, that there was in the history of the development of organised life any successive or graduated scale adhered to, or anything like a successive development of species in the same natural family, the newer being more highly organised than the older. The Cephalopoda, the most highly organised of all the Invertebrata, were the inhabitants of the most ancient seas with whose existence we are acquainted. Sauroid fish, those which most nearly approach the higher or Reptilian type, were among the first created of the finny tribes. Of the reptilian, lacertine, and crocodilian animals, it was by no means those of least complicated organisation that accompanied the Batrachians during the close of the Palæozoic and the commencement of the Secondary period, and numberless other instances might be quoted, having the same tendency.

There is no such thing apparent in the works of the great Author of nature as profiting by the experience of past imperfections and errors. There is infinite variety in working out a plan which, even to our limited capacity, is shown to be of perfect beauty; and in this variety there is a constant harmony strikingly analogous to the operation of the laws which govern the material universe. The Palæontologist must now reject almost with ridicule the wild theories on this subject which have sometimes been indulged in during an earlier condition of his science.

in the considerations which I am now anxious to impress upon the mind of the reader; I shall not, therefore, make any apology for offering here a few remarks on the Report recently drawn up by Professor Edw. Forbes,* "On the Distribution of the Mollusca and Radiata of the Ægean Sea considered as bearing on Geology."

I have said that the *relative* value we may be inclined, as naturalists, to affix to certain differences in specific character, more especially in animals of low organisation, must have great influence on the extent by which we suppose strata to be separated in point of time, which are distinguished by such differences in the organisation of their inhabitants. And this I consider to be a fair statement of the case, especially with regard to those fragments of shells and other hard parts of marine animals which usually and very naturally form the largest portion of all the fossils of a district.

It will be manifest then, that, in order to affix this value rightly, we should know something of the differences that exist between animals living in the same latitudes and in the same seas, but at different parts of those seas, whether such differences have regard to depth, shelter, sea-bottom, or any other circumstances. Until some distinct knowledge of this kind is arrived at, we may indeed be convinced of the existence of real differences; but we must be unable to interpret accurately their geological meaning.

It is just this useful work that has been undertaken and, so far as the Ægean Sea is concerned, I may say accomplished, by Professor Forbes, and the results he has arrived at possess the highest interest for the Palæontologist and the Geologist.

His general conclusions seem to be these: (1) that in-

* Report of the Meeting of the British Association in 1843, p. 2, *et seq.*

crease in depth has the same kind of effect on a marine fauna that increase of height has on a terrestrial one, each additional depth in the same sea exhibiting a corresponding approach to the littoral fauna of a colder climate.* (2.) That with regard to most species of marine animals and vegetables they are not distributed indifferently, but inhabit certain localities in the bed of the ocean; and that, when they have been thus occupied for a time, such localities become unfit for their longer existence, and they either migrate† or die out; but it appears that they also have fixed maxima of development in time as well as in depth and geographic space.‡ (3.) That species having an extensive range in depth, are precisely those which have also a wide geographic range. (4.) That below a depth of 300 fathoms uniform deposits of fine mud are probably going on in most seas, without the admixture of organic remains, and that those localities in which fossiliferous beds are now being deposited, are probably, with few exceptions, at no great distance from land.

* The temperature of the ocean is known to diminish from the surface downwards, and this diminution proceeds at the mean rate of about 1° Fah. in twenty-five fathoms in tropical, and 1° in twenty-eight fathoms in temperate latitudes. It would also appear that there is a depth below which no diminution takes place. In polar seas, where the average annual temperature of the surface is below 38° Fah., the colder water descends and is replaced by warmer from below. It would thus appear that there is a subaqueous surface of constant equal temperature in the deep waters of the ocean, but it is probably far below the level at which life exists, at least throughout a great part of the globe.

† Professor Forbes has shown by actual examples that many mollusca, not considered to possess locomotive powers, do actually migrate in a larva state.

‡ By maxima of development is meant that when these organised beings are first introduced to a locality, they are few in number, and not possessed of the vital energy, or attaining the magnitude which afterwards characterises them, but that they gradually or rapidly increase in number, and after a time again diminish. When most abundant they are said to have reached a maximum of development in time. In depth again the same thing happens, a certain depth being most favourable, and presenting the maximum of development. And it is also found that there is some one favoured locality, where each species attains its maximum—the maximum of geographic space. See Forbes's Report, *ante* cit. p. 45.

One more result, of considerable interest, is also derived from these researches of Professor Forbes, namely, that very few indeed of the species of fossils most abundant in the neighbouring Tertiary formations, and supposed to belong to extinct species, are found at all, at any depth in the Ægean Sea, so that by these investigations the calculations of Geologists are not disturbed.

The bearing of these conclusions upon that part of Geology now under consideration is immediate and evident. It is clear, in the first place, that we are not at liberty to assume the destruction of a species because it is replaced, apparently without cause, by another; but that the disappearance of an entire group, and its replacement by a new and different one, could hardly be effected without the lapse of a considerable period of time, or a great change of circumstances. An alteration in level, not amounting to more than a few fathoms, is, however, sufficient to produce that difference in the littoral and shallow depths near the surface which swarm with life, although a much greater change would hardly produce a visible effect in more considerable depths. If, then, we are able to determine whether a given fossiliferous bed was deposited at a certain depth below the surface of the sea, we may hope to discover the value of the change that appears between its fauna and that of a bed immediately above or below it.

In the next place, if marine animals are strictly confined to certain depths, or even if their development is greatly more perfect at certain depths than at others, a succession of movements, tending to elevate or depress the bed of a sea, would, if sufficiently frequent, cause the destruction of all these species, or their migration to distant parts. If the movements were sufficiently extensive or rapid, the destruction must be complete; and this might be the case, probably, in the course of movements scarcely greater than

those which have been known to take place on the earth since man was an inhabitant of it. After such an event, also, a considerable period would necessarily elapse before, in the natural course of things, a new group of animals would establish themselves, even supposing the circumstances favourable for their development. During this interval many species entirely new may have been introduced.

Thus, then, we arrive at the point which it was my object to reach in this discussion. It appears that there are no identical species between the fossils of the Palæozoic and of the Secondary period, but there are some general resemblances. There is, therefore, every probability of considerable disturbance having taken place; but there is no evidence of anything like a completely new creation consequent upon a general destruction of species. I should be inclined, therefore, in the present condition of this part of geological science, to speak of the line of demarcation between Palæozoic and Secondary, as sufficiently distinct for the purposes of classification, but as insufficient to warrant any sweeping conclusions with regard to an entirely new creation of organic beings.

With regard to the formation of the Lias, next in order of superposition to the sandstones which form the base of the Secondary rocks, it must have been deposited under circumstances so different, zoologically, from those which obtained in the arenaceous beds, that we have no right to form any general conclusions as to the amount of real difference that may have existed generally in the earth's inhabitants. We can, at the most, only compare the Muschelkalk with some of the calcareous bands in the Lias, but it must be acknowledged that the result of this comparison tends to prove that considerable change had taken place, and that,

so far as the evidence reaches, the establishment of the groups as distinct, is a valid one.

The Lias is succeeded by the great and extremely varied series to which the name Oolitic is applied. To the different beds of this remarkable and interesting group of deposits, it may not be too much to hope that a careful and intelligent application of some of the principles laid down by Professor Forbes may before long take place. The result of such a reconsideration of the Oolites, it is, perhaps, quite impossible even to conjecture; but there can be no doubt that it might lead to a knowledge of the circumstances of deposition of these beds greatly needed and likely to be of the highest advantage. It is probable that many of the beds, at any rate, were littoral or deposited near a sea-shore, and at no great depth of water; but others would appear to belong to lower zones. Perhaps, so rich is England in the beds of this period, we might ultimately find in our own country a key to the whole subject of Secondary fossils, and reduce to order the undigested masses of facts that have long been accumulating with reference to them. Materials are not wanting in different museums, both public and private, for the elucidation of a number of results, which could not but prove of great importance in their general bearing upon Geology.

The close of the Oolitic period is marked by the presence of a number of fossils, in beds which indicate not only the vicinity of land, but the existence of a great river or a lake of fresh water. And although the thickness of these deposits is very considerable, and there are many remarkable and complete changes observable in comparing the fauna of any of the newer Oolitic rocks with those of the succeeding marine period, when the Cretaceous deposits commenced, there exist many analogies and resemblances, not only in

animals of lower organisation, but even in the reptiles which so remarkably characterised the whole Secondary period. No amount of change hitherto detected between rocks so very far removed in space as the Lias and the Green-sand, can in any way disprove or detract from the value of the fact, that one species at least, and two very remarkable genera, of reptiles, likely from their marine habits to possess a great range in time as well as space, are actually common to both formations, ranging through all that are intermediate. Thus it may ultimately be proved, that the step from the Triassic to the Cretaceous group is comparatively inconsiderable, although we are presented with so rich a variety of illustration of the intermediate or middle Secondary period.

Lastly, the Cretaceous system, formed, as it would appear, for the most part, by deposits in deep water, and a considerable proportion of it not far from the zero of animal life, offers in different parts of Europe great material for study and research, also in connexion with the views put forward by Professor Forbes. That the general conditions of its fauna are such as to justify a comparison with the faunas of existing seas, there can be no reasonable doubt, and it is certain that the approximation is much closer than when we consider the fossils of more ancient periods.

But, although this is true, there is no absolute identity even in the groups which might be expected to exhibit some evidence of analogy. With the deposition of the chalk terminates, it would appear, in all parts of the known world, the ancient condition of organised beings.

And here it must be observed that the break in the Zoological sequence observable at this point, (at the conclusion, that is, of the Secondary period,) is far more striking

and persistent, and characterised by departures far greater in amount, and more important in their nature, than is the case with the other and corresponding one, after which the deposit of the Secondary rocks commenced. The materials on which the conclusions rest are more numerous, they embrace classes of facts of much wider generality, and they indicate an amount of change much more considerable. The mass of evidence on this subject is, indeed, so great, that even if it shall hereafter appear that absolute identity of specific character exists between a few species of animals found in the Secondary and newer strata, the general force of the conclusion can hardly be invalidated; and it will still remain true that the thousands and tens of thousands of species, introduced upon the earth since the chalk was deposited, are to all intents and purposes totally different from, and have no relations with, those of a more ancient period, whose remains are found fossil in Secondary rocks. All the animals and vegetables I have as yet described are, in the proper and strict sense of the word, *extinct*. They are the memorials that remain of Nature as she existed in a former condition, which has now passed away, and with the chalk we close, as it were, one great volume of the history of animated creation. Everything up to this point belongs to the past; everything on this side of it may be ranked among indications of the present. New forms, new types of organisation, corresponding to different habits and altered circumstances, now replace those which have passed away. The conditions under which animals and vegetables lived were changed, and a new epoch commenced upon the earth.

If then the view which I have taken is correct, and there has been a progressive change, indicating a distinct

plan in gradual development throughout the earth's history, I think that Geologists are in a condition to claim that degree of serious attention which is due to the promulgators of newly-discovered and important truths in the history of nature. For if there is evidence of constant succession, and of a definite order in creation, this is, indeed, more than could be anticipated from the study of existing nature; and it opens to our view a magnificent perspective, and may enable us to frame for ourselves an idea of the plan of Creation, far grander and more comprehensive, and more worthy of the great Creator, than any that our unassisted imagination could suggest. The plan, as it thus appears, is simple, vast, and unlimited by considerations of time or space. It comprehends all conditions under which our globe may have existed. It provides for the peopling of that globe under all circumstances consonant with the persistence of the equally simple and comprehensive laws which govern matter, and it contains within itself a beautiful unity and general symmetry in the midst of an endless variety of detail.

The making known of this plan has been one of the results already attained by Geology, and it is a result worth attaining, for it is knowledge of a high and useful kind. I have dwelt upon it now, because it naturally falls into my subject at this point, when I am about to quit the consideration of that which I have called the past, and when the reader is placed on the threshold of that which has reference to the present.

APPENDIX TO VOL. I.

ON THE SAUROID FISH CHARACTERISTIC OF THE MAGNESIAN LIMESTONE.

(*Vide* p. 282.)

The recent completion of the great work by M. Agassiz on Fossil Fishes—certainly one of the most valuable contributions Palæontology has received—enables me to give some account of the two very characteristic genera of Heterocercal fish of the Sauroid family, the Pygopterus and Acrolepis, found in the Magnesian limestone, and alluded to, but undescribed, in the body of the work.

The genus *Pygopterus* is very strikingly marked by the excessive development of its fins. The skeleton is robust, and the vertebræ broader than they are long. The scales are very small in proportion to the size of the body, they are smooth, rhomboidal, and extend not only over the body, but even encroach upon the fins, and are continued nearly to the extremity of the upper lobe of the tail. The caudal fin is very powerful, and its lobes unequal, the lower one being united to a very long anal fin continued along a considerable part of the belly; all the fins have rows of spines projecting from them, which gradually diminish in size to the extremity. The upper jaw extends beyond the lower one, and both are armed with pointed conical teeth, placed along and bedded in the jaw with regular interspaces. The teeth

are analogous in their structure to those of the recent genus Polypterus.

The other Magnesian limestone genus, the *Acrolepis*, is most remarkably characterised by the peculiar structure of its scales. These are of a rhomboidal shape, and of nearly equal size over all parts of the body, but their surface, instead of being smooth, is ornamented with one or more large longitudinal wrinkles, irregularly running into one another, and readily mistaken for the edges of scales. This wrinkled structure is found, also, on the bones of the head, and there forms a more continuous and complicated net-work of a very singular appearance.

The arrangement of the fins is nearly the same as in Pygopterus, but although very large and powerful, the swimming apparatus is not so remarkably developed as in that genus. The upper lobe of the tail differs from the lower, not only by its larger proportions, but also in the nature of its covering, although both lobes are provided with scales.

The head in both the known species of this genus is large, but short, the snout rather pointed, and the jaws armed with strong conical teeth placed close together.

END OF THE FIRST VOLUME.

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